AN INVESTIGATION INTO THE USE OF CONSTRUCTION DELAY AND DISRUPTION ANALYSIS METHODOLOGIES

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Declaration

This work or any part thereof has not previously been presented in any form to the University or to any other body whether for the purposes of assessment, publication or for any other purpose. Save for any express acknowledgment references and/or bibliographies cited in the work, I confirm that the intellectual contents of the work are the result of my own efforts and no other person.

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ABSTRACT

Delay and disruption (DD) to contractors' progress, often resulting in time and cost overruns, are a major source of claims and disputes in the construction industry. At the heart of the matter in dispute is often the question of the extent of each contracting party's responsibility for the delayed project completion and extra cost incurred. Various methodologies have been developed over the years as aids to answering this question. Whilst much has been written about DD, there is limited information on the extent of use of these methodologies in practice. The research reported in this thesis was initiated to investigate these issues in the UK, towards developing a framework for improving DD analysis. The methodology adopted in undertaking this research was the mixed method approach involving first, a detailed review of the relevant literature, followed by an industry-wide survey on the use of these methodologies and associated problems. Following this, interviews were conducted to investigate the identified problems in more depth. The data collected were analysed, with the aid of SPSS and Excel, using a variety of statistical methods including descriptive statistics analysis, relative index analysis, Kendall's concordance and factor analysis. The key finding was that DD analysis methodologies reported in the literature as having major weaknesses are the most widely used in practice mainly due to deficiencies in programming and record keeping practice. To facilitate the use of more reliable methodologies, which ensure more successful claims resolution with fewer chances of disputes, a framework has been developed comprising of: (i) best practice recommendations for promoting better record-keeping and programming practice and; (ii) a model for assisting analysts in their selection of appropriate delay analysis methodology for any claims situation. This model was validated by means of experts' review via a survey and the findings obtained suggest that the model is valuable and suitable for use in practice. Finally, areas for further research were identified.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF CASES

LIST OF ABBREVIATIONS

AACE	Association for the Advancement of Cost Engineering
A/E	Architect/Engineer
AHP	Analytical Hierarchy Process
ACWP	Actual Cost of Work Performed
All ER	All English Law Reports
ADR	Alternative Dispute Resolution
BCA	Federal Board of Contract Appeals
B.C.S.Ct	British Columbia Supreme Court
BCWP	Budgeted Cost of Work Performed
BCWS	Budgeted Cost of Work Schedule
BLR	Building Law Report
CA	Cluster Analysis
CILL	Construction Industry Law Letter
CIOB	Chartered Institute of Building
Cl. Ct.	United States Claims Court
Con L.R.	Construction Law Reports
CPA	Critical Path Analysis
CPM	Critical Path Method
DAM	Delay Analysis Methodology
DD	Delay and Disruption
DDA	Delay and Disruption Analysis
DM	Decision Maker
DSAM	Disruption Analysis Methodology

EC	Excusable Compensable Delay
EN	Excusable Non-compensable Delay
EVM	Earned Value Management
EWHC	England and Wales High Court
FST	Fuzzy Set Theory
F.2d	Federal Reporter, Second Series
ICE	Institute of Civil Engineers
ICT	Information and Communication Technology
KBES	Knowledge-based Expert Systems
KMO	Kaiser-Meyer-Olkin
LP	Linear programming
MAA	Multi-Attribute Analysis
MAUT	Multi-Attribute Utility Theory
MCAA	Mechanical Contractors' Association of America
MCDM	Multi-Criteria Decision-Making
MDA	Multivariate Discriminate Analysis
MOA	Multiple-Objective Analysis
NCE	New Civil Engineer
NN	Nonexcusable Noncompensable Delays
PERT	Programme Evaluation Review Technique
QS	Quantity Surveyor
RI	Relative index
RICS	Royal Institute of Chartered Surveyors
SCL	Society of Construction Law
SMAA	Scoring Multi-Attribute Analysis
SPSS	Statistical Package for the Social Sciences

TCC	Technology and Construction Court
W	Kendall’s coefficient of concordance

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DEDICATION

This research is dedicated to my Father, Braimah Bukari, Mother, Mrs. Mariama Braimah, Brothers and Sisters and my family, my Wife, Mariatu Nuhu and Children, Hisham, Abdul-Nasir and Adnan Nuhu.

CHAPTER ONE

1 GENERAL INTRODUCTION

1.1 Background to the research

The time and cost for performance of a project are usually of the essence to the employer and the contractor. This is because late completion of projects can deny employers the benefits or profits that accrue through use of the project and may also expose them to serious financial and economic risks such as high interest rates and loss of market opportunities. On the contractor's side, delay in completion entails additional cost accruing from extended home office and site office overheads, labour and equipment standby costs and other intangible cost such as opportunity cost. Despite these effects, it is sadly all too common that most projects are not completed within the agreed contract period and for the price it was tendered for. Notable recent examples in the UK include the British Library, the Millennium Dome, the Scottish Parliament Building, the Docklands Light Railway, The Brompton Hospital, the West Coast Mainline Upgrade for Network Rail, the Jubilee Line Tube Extension, and the Wembley Stadium, which suffered huge time and cost overruns. Not surprisingly, many landmark reports on review of the UK construction industry (NEDO, 1983; Latham, 1994; Egan, 1998; 2002; OGC, 2003) identified delays and disruptions (DD) associated with project delivery as major issues.

The contractual approach to dealing with DD issues has been to provide in the contract document circumstances that are likely to cause project delay and the mechanism for resolving them. Typically, most contracts excuse contractors from the consequences and/or allow compensation for DD arising from events or

circumstances of which the risk is borne by the employer or is shared between the parties. Provisions are also made for allowing the employer to recover liquidated damages from the contractor for failure to deliver the project within the contract performance period. Liquidated damages clauses entitle the employer to recovery of a specified sum of money for each day or week of contractor culpable delay. In both instances, a detailed schedule analysis is required to investigate the events that have actually caused the project to experience time and cost overruns in order to determine the right amount of compensations for the injured party. This task is often termed "Delay and Disruption Analysis (DDA)" and is usually undertaken using various techniques mostly based on critical path method (CPM), now a recognised tool for this function (Wickwire *et al.*, 1989; Kallo, 1996b).

In most cases, however, DD issues which ought to be managed in the course of a project are translated into claims situations and subsequently disputes (Diekmann and Nelson, 1985; Semple *et al*., 1994; Kumaraswamy, 1997; Kumaraswamy and Chan, 1998). The disputes are often resolved through expensive forms of dispute resolution settings such as court litigation. Significant cost usually flows from this state of affairs with dire consequences to all project stakeholders and the society at large. It has been estimated that such disputes cost the UK construction industry alone £8billion annually (Pickavance, 2003; Pickavance, 2005, p.322).

Consequently, there has been much desire to reduce or avoid DD claims disputes and this has created considerable research interest among researchers and practitioners. Most of the studies undertaken can be classified under six categories as indicated in Table 1.1. The first, and most populated, consists of studies aimed at the development

of productivity charts/models for analysing the impacts of productivity factors as a result of disruptions. The second group covers studies aimed at improving existing disruption analysis methodologies (DSAMs). The third category consists of those studies aimed at development or refinements to existing delay analysis methodologies (DAMs) to address a number of issues that affect analysis results.

The fourth group of studies has been aimed at development of Information and Communication Technology (ICT) support tools for performing delay analysis such as knowledge-based systems and other decision support systems. The fifth group involves the development of systems dynamics models for analysing causation in DD claims resolution. The question of causation concerns the need for a claimant to prove not only that a risk allocated to the other party occurred but also that it caused the delay and/or disruption complained of. Finally, there have been surveys into some aspects of DD claims analysis.

Despite the increased attention, DD claims resolution continues to pose a great challenge for project employers and contractors at all levels of the supply chain (Pickavance, 2005; Pinnell, 2005). Stimulated by this state, this research was initiated to investigate the current use of the methodologies for analysing DD claims in practice and the associated problems towards developing an appropriate framework for improving practice. To clearly define the scope of the research, DD claims are briefly defined in the next section.

Table 1.1 Studies on methodologies for analysing DD claims

Aim of study/problem addressed	Literature
Development of productivity charts/models for assessing the impacts of disruption due to:	
adverse weather	Grimm and Wagner (1974); NECA (1974); Harris and McCaffer (1975); Hancher and Abd-Elkhalek (1998); Thomas *et al*.(1999).
variation or change orders	Moselhi *et al.* (1991); Thomas and Napolitan (1995); Thomas and Oloufa (1995); Ibbs (1997); Hanna *et al.* (1999a, 1999b); Hanna and Gunduz (2004); Ibbs (2005); Moselhi *et al* (2005)
overtime	BRT (1980); CII (1988, 1994); Blomberg (1988); Thomas (1992); Hanna *et al*.(2005).
learning curve effects	Verschuren (1985); Thomas *et al.*(1986); Everett and Farghal (1994)
acceleration and congestion	Thomas and Jansma (1985); Thomas *et al.* (1989); Horner and Talhouni (1995)
Improvements to existing DSAMs	Zink (1990); Finke (1997a, 1998a, 1998b); Thomas and Zavrski (1999); Presnell (2003); Gulezian and Frederick (2003); Norfleet (2005); Ibbs and Liu (2005)
Development or refinements to existing DAMs to address issues of:	
concurrent delays	Kraiem and Diekman (1987); Arditi and Robinson, (1995); Galloway and Nielsen (1990); Alkass *et al.*, (1996); Ng *et al*. (2004); Mbabazi *et al.*(2005)
migration of the critical path	Reams (1989); Bordoli and Baldwin (1998); Finke (1997b, 1999); Shi *et al.* (2001); Sandlin *et al.* (2004); Hegazy and Zhang (2005); Kim *et al.* (2005); Ottesen, (2006).
ownership of float	Chehayeb *et al.*(1995); Gothand (2003); Al-Gahtani and Mohan (2005)
disruption, acceleration and resources allocation	Arditi and Patel (1989); Ryu, *et al*. (2003); Lee *et al.*(2005); Ibbs and Nguyen (2007)
Application of Information and Communication Technology in delay analysis	
knowledge-based systems	Moselhi and Nicholas (1990); Raid *et al.* (1991); Diekmann and Kim (1992)
decision support systems	Reams (1987); Bubbers and Christian (1992); Yates (1993); Moselhi and El-Rayes (2002)
Computer-aided approaches	Mazerolle and Alkass (1993); Battikha and Alkass (1994); Alkass *et al.*(1995); Lucas (2002); Oliveros and Fayek (2005)
Applications of systems dynamics in DD analysis	Williams *et al*. (1995); Ackerman *et al.* (1997); Chapman (1998); Howick and Eden (2001); Williams *et al.* (2003); Eden *et al.* (2004); Cooper *et al.* (2004).
Surveys into aspects of delay analysis including practitioners views' on DAMs, concurrent delays and float ownership.	Scott (1993a); Scott (1997); Bordoli and Baldwin (1998); Harris and Scott (2001); Scott and Harris (2004); Kumaraswamy and Yogeswaran (2003)

1.2 Delay and Disruption Claims

The term ‘claim’ is defined in the context of construction projects as any application by the contractor whether for an extension of time, payment, or otherwise, which arises other than under the ordinary contract provisions for payment of the value of work (Powell-Smith and Stephenson, 1989; Trickey and Hackett, 2001). There are four main bases on which a claim may be made in law (Powell-Smith and Stephenson, 1989):

under express contract conditions-contractual claims;

for breach of contract at common law- common law claims;

on quasi-contractual or restitutionary basis- *quantum meruit* claims; and

on ‘out of kindness’ basis-*ex gratia* awards or claims.

The majority of contractors’ claims are contractual in nature and often result from the project’s delays and/or disruption (Diekmann and Nelson, 1985; Semple *et al.*, 1994; Kumaraswamy, 1997), which are caused by matters that are the employer’s responsibility, the contractor’s own responsibility or by neither party (e.g. an act of god). The successful settlement of a typical DD claims usually requires that the claimants goes through five main processes (Lee, 1983; Williams *et al.,* 2003; Klanac and Nelson, 2004):

(i) establishment of contractual/legal basis for the claim(Liability);

(ii) establishment of causal link between each delay and/or disruption event and the resulting extended duration and/or additional cost (Causation);

(iii) evaluation of effect and quantify the amount of time and/or cost of the impacts (Quantum);

(iv) compilation and submission of claim; and

(v) Negotiation of settlement.

The second and third elements are relatively difficult to deal with than the rest (Keane, 1994; Carnell, 2000; Klanac and Nelson, 2004). This research is therefore concerned with the methodologies for proving or disproving these elements in claims of contractual nature, typically allowed for by most of the standard form of contracts.

It is noteworthy that delay claims and that of disruption are completely two different heads of claims, although the two terms are often spoken of together as “delay and disruption”. Different methodologies are therefore used for analysing claims on delays and those based upon disruption. However, due to the close association between events that cause project DD, the proof of a typical claim may require a combination of the two separate methodologies in order to develop a holistic argument for contractual entitlement to additional time and cost. Detailed distinction between the two types of claims and their methodologies are provided in Chapter 5.

1.3 Problem definition

The task of justifying and quantifying the effect of each DD event required to be satisfied for the proof of causation and quantum is well recognised as an extremely difficult undertaking. This is partly due to the nature of DD events itself. Not only do these events come from a variety of sources (Borcherding, 1978; Hanna and Heale, 1994; Kumaraswamy, 1997), they also have different effects and implications resulting in complex ramifications, creating considerable difficulty to practitioners in the claims resolution. As an example, a delay in the issue of drawings to a contractor can bring about consequences such as out-of-sequence work, work stoppages, poor

morale and diminishing of learning curve. The effect of these is often the contractor working less efficiently than originally anticipated, manifesting itself in additional cost being incurred and/or delay to the project completion as a whole. To overcome such delay, the contractor may be asked to accelerate the work or may do this constructively, which may result in parallel working with concomitant disruptions impacting negatively on productivity.

The above example shows how a very simple delay event can generate into a situation of a very complex interaction of a combination of different events, which could be difficult to unravel and sort out clearly into their individual causes and effects. A more complex situation is often triggered when a number of changes or variations are ordered by the employer. The cumulative (synergistic) impacts of multiple changes are particularly troublesome to resolve as described by a Construction Industry Institute report (Hester *et al*. 1991) - *"when there are multiple changes on a project and they act in sequence or concurrently there is a compounding effect – this is the most damaging consequence for a project and the most difficult to understand and manage. The net effect of the individual effect of the individual changes is much greater than a sum of the individual parts"*.

The challenging nature of resolving DD claims has resulted, in part, in numerous initiatives from researchers and practitioners over the years with the aim of ensuring amicable resolution of claims, or if possible, for complete avoidance of claims situations. These initiatives include the following.

First, there is the view that, in order to avoid disputes from claims, contracting parties should begin projects with suitable contract languages and with appropriate

Alternative Dispute Resolution (ADR) mechanism (Levitt *et al*., 1980; Diekmann and Girard, 1995). Under this, particular areas of attention suggested include the adoption of equitable risk allocation and better understanding and interpretation of contractual provisions (Perry, 1986; Thomas *et al*., 1994; Revay, 1995). Equitable risk allocation entails recognising known project risks and properly assigning them to the appropriate party. This is done based on a number of principles with the principal one being that the responsibility for a particular risk under the contract should be assigned to the party that has the competence and capability to deal with it, should it arise (Ward *et al*., 1991; Kangari, 1995b; Smith, 1995; Zack, 1995; Megens, 1997). For example, it is unreasonable to assign the risk of project design to the contractor in projects procured using the traditional form of procurement. As a dispute-reduction strategy, the concept of risk allocation has been employed, over the past decade, to change the way projects are procured in the UK. These include the amendments of procurement routes, promotion of innovative procurement strategies such as Design and Build, Partnering and Public-Private Partnership/Private Finance Initiative. The use of these procurement methods, particularly for major works is highly encouraged by the UK government (CPA, 1993). This has probably led to their increase use by the industry as various surveys suggest (Ndekugri and Turner, 1994; Ridout, 1999; Langdon and Everest, 1996; 2002). The Engineering and Construction Contract developed in the UK by the Institute of Civil Engineers (ICE, 1995) is also contended to be one of the most innovative contract forms aimed at ensuring dispute-free projects (Latham, 1994; Revay, 1995). The main departures of this form from the other forms is that, not only does it divides the historical role of the Engineer/Architect between the Project Manager, Supervisor, the designer and the Adjudicator, it also deals with claims situation in a more comprehensive and effective manner.

Second, there is the view that to minimise claims, more time and money should be allocated to project's design phase in order to reduce the number of changes to the contract (Wilson, 1982; Revay, 1992; Zack, 1997). This recommendation is based on the fact that majority of DD claims are caused by differing site conditions, variations, inadequate and inaccurate design information (Ibbs and Ashley, 1987; Choy and Sidwell, 1991; Kumaraswamy, 1997). Areas of particular attention recommended include increasing the design period, improving ground investigations and employing proper documentation checks. However, even if such suggestions are possible to implement, which is not always so in practice, the nature of construction is such that changes to the work are to be expected no matter how much effort is expended on the design. Changes are inevitable due to the high level of uncertainty conditions in which construction projects operates (Laufer and Tucker, 1988; Laufer *et al.* 1992) and the inability of designers to provide for all possible eventualities.

Thirdly, there is the approach that suggests quick resolution of emerging DD claims situations before they develop into complex disputes. Notable example adopting this is the *Delay and Disruption Protocol* developed recently by the UK's Society of Construction Law (SCL), a body comprising of highly experienced engineers, architects, quantity surveyors and lawyers. Intended as a good practice guidance, the protocol seeks to prevent 'wait and see' approach by promoting the resolution of matters of extension of time and cost compensations on an on-going basis (SCL, 2002). Although, to a large extent, the protocol has had a good reception by the industry, the main criticism of it has been on the potential difficulty of implementing it in practice. Most of the protocol's recommendations are based on proper preparation and maintenance of programmes and other project records, which are

thought to be at variance with current industry practice (Birkby, 2002; McCaffrey, 2003). There have also been insignificant movement on the part of drafting bodies of standard forms in adopting the recommendations of the protocols (Pickavance, 2005).

Although the above initiatives have the potential of reducing disputes, it appears they have not had substantial impact considering the fact that DD claims still remain a major source of disputes as noted before. A critical review of the literature suggested that the reason for the continuing difficulty with DD claims resolution can be attributed to a number of problems including: lack of uniformity in the application of DD methodologies, lack of sufficient guidance from contracts and case law on DDA and poor planning and programming practice.

1.3.1 Lack of uniformity in the application of DD methodologies

There are several acceptable DDA methodologies each requiring a unique set of procedures and assumptions in their application. The differences in their approaches coupled with the way individual analysts deal with some subjective aspects of the analysis often leads to results of staggeringly different levels of accuracy for any particular delay and/or disruption claims situation (Callahan *et al*., 1992; Alkass *et al.,* 1996; Bubshait and Cunningham, 1998; Stumpf, 2000; SCL, 2006). In addition, the various methodologies are known by different terminologies amongst practitioners, which can cause confusion to parties wanting to apply the same methodology. Sadly, there is lack of uniformity among practitioners as to the names of the various methodologies, what their application entails and the way to select an appropriate methodology for use in a given DD claims. For now, analysts rely on their own

judgement (Williams, 2003), based on their accumulated experience, expertise and intuition, which has been a recipe for disputes.

1.3.2 Lack of sufficient guidance from contracts and case law on DDA

Most forms of contract tend to limit their guidance on matters relating to DD claims to broad recommendations, which are prone to subjective interpretations. For instance, details of the principles governing the analysis of DD, such as methodological choice and how the various methodologies are to be applied are often lacking (Yogeswaran *et al*., 1998; Pickavance, 2005). This leads to much reliance on the judgement of the practitioners involved and thus much on which to disagree on.

Legal precedents on DDA matters, which may help provide guidance on the approach for the analysis is also unfortunately limited in the UK (Pickavance, 2005; Harris and Scott, 2001). This may be due, in part, to the fact that in the past many construction disputes in the UK have been resolved by arbitration and more frequently now by adjudication under the Housing Grants, Construction and Regeneration Acts 1996. The private nature of these disputes resolution forums has resulted in the publication of few decisions on DD disputes. The chances for practitioners to learn from the practical experience of others in their use of the methodologies have therefore been limited.

1.3.3 Poor planning and programming practice

Lastly, a number of researchers and commentators have decried that most contractors' programmes are poorly prepared and not properly updated (if updated at all) to reflect changes that occurred during the course of the project (Nahapiet and Nahapiet, 1985;

Yogeswaran *et al.*, 1998; Winter and Johnson, 2000). Such deficiencies in programming practice make it difficult for analysts to measure accurately the effect of various delay events on project completion, i.e. to perform delay analysis properly. This is because the most recognised and acceptable DAMs are based on construction programmes (typical of which is the CPM), which are required, *inter alia*, to reflect accurately what actually happened on site as the project progresses (Wickwire *et al.*, 1989; Pickavance, 2005; Bramble and Callahan, 2000).

In the light of these problems, it is important to question whether or not the various methodologies for performing DD analysis have been useful to practitioners. Unfortunately, there is very little empirical research for answering this question (see Bordoli and Baldwin (1998) and Harris and Scott (2001)). This research therefore hypothesises that a major source of the difficulty with DD claims resolution is the use of inappropriate methodologies for the analysis and such difficulty can be reduced by the development of an appropriate framework for improving DD analysis.

1.4 Aims and Objectives

In recognition of the above background, this research set out to develop an appropriate framework for improving existing DD analysis practice. The main aim of this research is thus to critically examine the existing methodologies for analysing DD claims with a view to identifying the problems associated with their current usage towards developing a framework for improvement. In pursuit of this aim, the main research objectives embraced the following:

to review the theoretical concepts and legal principles in DD claims resolutions;

- to identify and evaluate existing DD analysis methodologies and how they are most appropriately used;
- to investigate planning and programming issues affecting DD analysis;
- to investigate the current practice in the use of these methodologies in the UK construction industry;
- to investigate the problems affecting the use of these methodologies in practice;
- to develop a framework for improving DD analysis in the form of good practice recommendations;
- to develop and validate a model for selecting appropriate delay analysis methodology (DAM);
- to identify areas of further research and development needs of DD analysis.

1.5 Research Questions

The main research questions this research aims to address are:

- What is the current practice on the use of DD analysis methodologies and associated problems?
- What is the appropriate framework for improving DD analysis in the UK?

1.6 Research Methodology

The issues to be dealt with in the research were very complex covering several domains: law, human behaviour and cost and time analysis. Therefore a methodological pluralism involving both qualitative and quantitative data was utilised. The application and justification of such methodology is detailed in Chapter 2. An overview of the main steps followed is, however, given below.

A detailed literature search and review were first undertaken to provide theoretical background and context of the research. This review covered the theoretical and legal principles underlining DD analysis, planning and programming issues and evaluation of existing DDA methodologies with regard to their applications, strengths and weaknesses. Through the review, these methodologies and other issues affecting their use were identified for further investigation. This investigation involved an initial pilot survey followed by a nation-wide cross-sectional questionnaire survey of construction and consulting organisations within UK on use of the methodologies. The results of the survey and the review pointed to the need for further in-depth investigation into the major problems affecting DD analysis practice. This investigation was carried out using interviews. The data collected were analysed using a number statistical techniques including descriptive statistics, relative index analysis, Correlation analysis, Factor analysis, Kendall's Concordance and Chi-square tests.

Finally, the findings were used to draw up recommendations as to best practice and develop a DAM selection model, which was then validated by means of experts' views using postal surveys. A summary of these results are as follows.

1.7 Summary of Findings, Conclusions and Recommendations

1.7.1 Research findings and Conclusions

A thorough review of the relevant literature on DD identified a number of principles underlining DD claims analysis, including: the requirements for the preparation or assessing of such claims, the resolution of concurrent delays and the ownership of float. The CPM of programming was identified as an essential requirement for performing DD analysis. Analyses based on this technique are, however, required to

be carried out in a clear, balanced and objective manner, in addition to backing them with good factual evidence.

The review also identified the existing methodologies for analysing DD and issues of planning and programming practice that tend to affect their usage. Two groups of methodologies were reviewed, one for analysing delays (DAMs, mostly based on CPM) and the other for analysing disruptions (DSAMs). These methodologies are known by different terminologies among practitioners. Each has its own strengths and weaknesses, although some are more rigorous than others. Furthermore, there is no common agreement among researchers and practitioners as to which is more reliable or acceptable for use. The general view has been that no single methodology is universally suitable for all claims situations and that the best methodology for any situation should be selected based on a number of criteria.

In determining what framework might be useful for improving DD analysis, an area that was investigated was the use of existing DD analysis methodologies in practice and associated problems. The primary data from this investigation came from 63 contractors and 67 consultants who took part in an industry-wide questionnaire survey, with 15 of the contractors further participating in a subsequent interview. The majority of the respondents were in positions of high levels of responsibility in large organisations and had been dealing with DD claims for more than 16 years. They were therefore ideally suited to participate and respond to the issues investigated in this research. The main findings from the survey are as follows:

1. The majority of the respondents felt that DD claims are not often resolved contemporaneously in the course of project as is commonly recommended. They are rather resolved toward the end of the project or after and are also often attended by considerable difficulties leading to frequent disputes. These findings further justified the need for undertaking this research

2. DD analysis is a multidisciplinary task requiring the input of many experts from construction and consulting organisations. Quantity surveyors have the greatest involvement in all these organisations. This conflicts with provisions in most forms of contract as to the leading role of the Architect/Engineer in contractors' claims assessments. This suggests the need for reviewing QSs functions towards better management of this role and their training needs.

3. The most frequent reasons for disputes over DD claims are: failure to establish causal link, followed by inadequate supporting documentation on quantum and then insufficient breakdown of claims amount. This suggests that the methodologies for proving causation and good records are important considerations in research seeking to avoid or reduce claims disputes.

4. DD analysis methodologies that are reported in literature to have major weaknesses were the most well-known and widely used methodologies. Lack of adequate project information, poorly updated programmes and baseline programme not in CPM format were reported as factors posing obstacles to the use of these methodologies, particularly the more accurate and reliable ones.

Further investigation using interviews was undertaken to understand the underlying causes of the problems affecting DD analysis. The results disclosed four main causes. First, contractors often prepare their construction programmes in linked bar chart format, which have logic difficulties when used for projects with complex sequence of activities. Such programmes do not facilitate the use of more accurate DAMs as they are highly based on CPM. Secondly, most contractors produce their programmes using planning software packages that do not possess adequate functionalities for performing forensic analysis of project delays. Thirdly, programmes produced are usually not resource-loaded and levelled, which affects their reliability as a source of information for undertaking DD analysis. Finally, contractors do not keep records of crew productivity for major activities, which makes it virtually impossible to analyse disruption claims using most reliable methodologies such as the measured mile technique.

1.7.2 Best Practice recommendations and DAM selection model

The above findings suggest contractors and consultants often resort to DD analysis methodologies that are incapable of producing results of high accuracy or reasonable precision/certainty and this has been a major source of disputes on DD claims. In seeking to address this problem, best practice recommendations that will promote better planning, programming and record keeping practice and facilitate the use of more reliable methodologies were made as follows.

1. Employers should make it a contractual requirement for contractors to provide a fully resource loaded and levelled baseline programme in CPM format, except for projects which are less complex. This should be produced using industry

standard planning software and submitted to the employer or its representative for review and acceptance. The programme should be accompanied by a method statement on which it was based.

2. The contract should provide for joint review of the programme by the parties for purposes of checking its reliability and modifying it if necessary or accept it as is. This review should examine the programme for flaws and errors in respect of the project scope, activity details, durations and relationships. The review should also serve as a means of reaching agreement on some aspects of the programme and its updating. Aspects that need to be agreed on include the planning software used, project calendar, unit of planning, preferential logics used, major assumptions made in estimating activities durations and any contingencies factored into the programme for managing risk. Other issues the need consideration are the mode and frequency of updating, float ownership, records to be kept and their contents and frequency of site progress reporting.

3. The final accepted programme and its updates should be submitted electronically to the employer or his representative in addition to hard copy versions. Each update should be accompanied by detailed progress report describing any changes in planned scope of project activities, their start and finish dates, logic and durations, which are inconsistent with the previous progress report.

4. Contractors should also be required to keep adequate documentation including records on daily site progress, original and actual job cost for each activities and records of crew productivity for major activities.

On the basis of the literature review and the findings, a particular problem area was also isolated for further consideration, namely: *claim parties usually adopt different methodologies for analysing delays which give rise to conflicting results and disagreement.* To redress this, the research has developed and validated a model for selecting the appropriate DAM, which can aid practitioners to arrive at a balance rather than partisan results.

The model is based on scoring competing DAMs on 18 selection criteria identified as relevant from the review of the literature and the questionnaire survey. The survey also established the relative important values of these criteria, which were then converted into their respective weights for use in the model. The application of the model involves first rating each DAM successively against each criterion in reflection of the extent to which each method is suitable for use given the criterion under consideration. The ratings from all the criteria are then multiplied by their respective weightings to obtain the suitability scores of the various methodologies. The total suitability score for each methodology is then computed by summing up all the suitability scores from the various criteria. The methodology with the highest total suitability score is to be selected as the most appropriate methodology for the delay analysis.

To ensure that the model is valid for use in practice it was subjected to validation. This involved an application of the model to a hypothetical case study followed by its review by experts via a questionnaire survey. The majority of the experts responded in favour of the model as to its significance to the industry, adequacy, completeness, comprehensibility and cost effectiveness. The main objection raised concerned a potential difficulty of parties being able to reach agreement on the ratings of the methods due to the fact that different views are held by practitioners on their attributes.

Finally, this research has identified a number of areas for further research. These include the need to: establish through research, the generally acceptable attributes and implementation procedures of the most common DAMs; and repeat the surveys into DAM selection factors, at periodic intervals, for purposes of updating the model to ensure its applicability over time.

1.8 Main Achievements and Contribution to Knowledge

In recent times, DD claims in construction and engineering projects are some of the most difficult and controversial disputes to resolve. Despite changing attitudes and modern procurement methods, difficulties in fair resolution of such claims still persist. In an attempt to redress this, this research carried out an investigation into the use of DDA methodologies and associated problems. This has culminated in the development of best practice recommendations which can assist claim parties to resolve DD matters with less difficulty, thereby avoiding unnecessary disputes and cost. The outcomes of the research offer many potential benefits to practitioners and researchers.

A summary of the major research achievements and contributions to knowledge arising from this research are as follows.

1. A review of existing DDA methodologies in use as reported in the literature. This provides up-to-date information on this subject matter, which would be very useful to researchers and practitioners investigating in this area.

2. The current status of DD analysis methodologies usage amongst UK construction organisation has been established based on questionnaire survey. Areas addressed by the survey included the level of use, acceptance and evaluation of factors influencing the selection of DAM. The findings of this investigation can be used as checklists against which common understanding between employers and contractors on DD claims matters can be promoted to enhance the chances of speedy and amicable settlement. This will particularly benefit practitioners in the UK given that the case law on these matters is limited.

3. An innovative framework for improving DD analysis practice has been developed; comprising of good practice recommendations and a model for selecting appropriate DAM. The model is intended to serve as a tool for assisting analysts in justifying their choice of DAM to their clients and/or the trier-of-fact when the contract is silent on the method to use. Claim parties can also rely on it if they have to come to an agreement on which DAM should be used for performing the claims analysis.

The findings of this research have been disseminated to industry practitioners and academic peers. Three peer-reviewed papers have been published and presented in various conferences: Braimah *et al.* (2006a), Braimah *et al*. (2006b) and Braimah *et al*. (2007). A fourth conference paper has been accepted for presentation in this year's COBRA conference (Braimah and Ndekugri, 2008). Two referred journal papers have also been accepted for publication in the *Journal of International Project Management* (Braimah and Ndekugri, 2007) and the ASCE *Journal of Construction Engineering and Management* (Ndekugri, *et al.,* 2008). Two other journal papers are currently in the pipeline (one in the review stage).

1.9 Structure of the Thesis

The thesis is organised in chapters, briefly described below. Figure 1.1 shows the major process of the research and how it links with these chapters.

***Chapter One* -** General Introduction: This presents a general overview of the thesis comprising of the research background, the research aims and objectives, the methodology adopted, the main achievements and contribution to knowledge. It also gives a general guide to the contents of the thesis.

***Chapter Two* -** Research Methodology: It explains the methodology adopted in carrying out the research, the reasons for adopting it and how it facilitated the achievement of the research objectives. It also sets out the survey procedure, selection of survey sample, procedures used in analysing data collected and its justification.

***Chapter Three* -** Theoretical concepts and legal principles in DD claims: This chapter reviews literature and case laws on DD claims as basis for identifying the accepted approaches required in the analysis of DD claims.

Chapter Four –Planning and Programming issues: This chapter reviews issues of planning and programming that affects DD analysis. Deficiencies in existing practice as reported in the literature and their possible causes were identified. This enabled the identification of important areas of programming for further empirical investigation.

Chapter Five **-** Existing DD analysis methodologies: This chapter identifies and evaluates the various DD methodologies mentioned in the literature. Methodologies purposely for analysing delays and those for disruptions, together with factors affecting their use are identified and reviewed critically.

***Chapter Six* -** Analysis and Discussion of Survey Results: This chapter reports on the findings of the questionnaire survey undertaken to establish the current state of DD analysis practice in the UK. This provided basis for the identification of associated major problems that were further investigated in-depth using interviews and also for the development of an appropriate framework for improvement.

***Chapter Seven*-** Programming issues affecting DD analysis: This chapter presents the results of interviews carried out to clarify and fully understand the main problematic issues affecting DD analysis.

Chapter Eight – A model for selecting the appropriate DAM: This chapter describe the development of a model designed to assist practitioners in their decision-making in selecting the appropriate DAM to use in a given claims situation.

Chapter Nine **-** Validation of the model. This chapter reports on the evaluation of the developed model, involving the application of the model to a hypothetical case study and its validation through experts review in a questionnaire survey.

Chapter Ten **-** Conclusions and Recommendations: The conclusions derived from the research and recommendations for promoting good practice are presented in this chapter. Also included are suggested recommendations for further research.

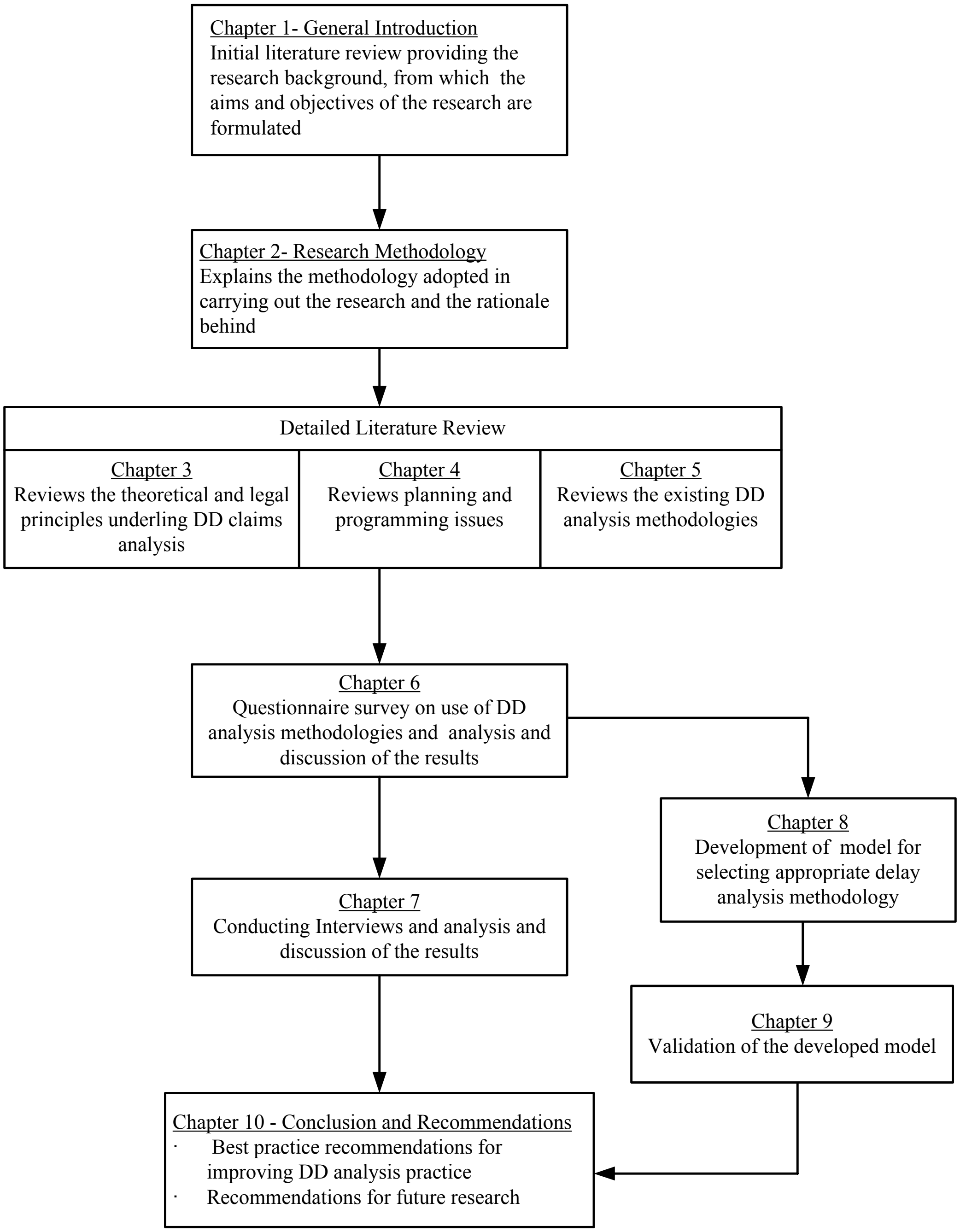

Figure 1.1 Flow chart showing the process of the research

CHAPTER TWO

2 RESEARCH METHODOLOGY

2.1 Introduction

This chapter addresses the research methodology adopted for capturing the data needed to achieve the aim and objectives of the research. It is organised in sections covering: (i) the research design and methods adopted; (ii) scope of the review of literature; (iii) sampling and administration of the postal survey; (iv) method used in analysing the data; (v) design and administration of interviews; (vi) best practice recommendations and a model for selecting appropriate DAM; and (vii) validation of the model.

2.2 Research Design and Methods

The nature of a research topic, its aims and objectives and the resources available largely determine its design (Gill and Johnson, 2002; Creswell, 2003). These criteria largely informed the research methodology developed for carrying out this research.

To begin with, the main research objectives were analysed to identify the basic questions that need to be addressed. The objectives posed a number of questions including:

to what extent are DD claims resolved during the course of a project?

to what extent are such claims transformed into disputes?

what are the reasons for unsatisfactory resolution of DD claims?

which types of staff in construction organisations provide inputs into DD claims preparations or assessment?

to what extent is industry aware of the methodologies for resolving DD claims?

to what extent are the methodologies used in practice?

what are the success rates of these methodologies in terms of settlement of claims without disputes that require resolution by a third party?

what are the factors considered in the selection of appropriate methodology for delay claims analysis?

what are the obstacles to the use of the methodologies in practice?

why are there problems in their use in practice?

how could current DD analysis practice be improved?

As a result of the multiplicity of the research questions and diversity in the types and sources of data required for answering these questions, it became apparent very early in the study that the data would be both qualitative and quantitative in nature. Superimposed on these characteristics of the research was the fact that the study objectives centered on the social aspects of DDA on which there is very little literature other than individual experiences captured in expert commentaries in journals and a handful of textbooks. These characteristics of the study belonged to those determined by Tashakorri and Teddlie (1998) and Creswell (2003) as requiring adoption of mixed methods research design approach. This involved a critical review of the literature and primary data collection at two different stages consecutively. Various research strategies such as experiments, survey, interviews, archival analysis and case studies were carefully considered first in deciding upon the most appropriate

method for collecting the data. Archival analysis and case studies were discounted as unsuitable given the sensitive and confidential nature of the subject matter of the research. Their application require access to materials such as records of actual DD claims and disputes materials, which is considered unlikely that most organisations will be willing to provide. Experiments in social sciences are field-based requiring extensive time and cost to conduct (De Vaus, 2002; Creswell, 2003) than this research could afford. This approach was thus also discounted, leaving surveys and interviews as the only appropriate options to rely upon.

A quantitative research strategy involving the use of a survey was adopted in the first stage for answering most of the 'what' questions to explore the current DD analysis practice. This was followed by an in-depth qualitative investigation of issues informed by the survey in answering most of the 'how' and 'why' questions. The survey also helped in the identification of appropriate interviewees. The following further examines the choice of survey and the data collection methods most appropriate to use in the light of the research problem for the first stage.

A major factor that influenced the choice of the survey strategy was the large and diverse nature of the research population, as delay claims are prevalent in different forms and in many different types of organisations (employers, contractors, sub-contractors and designers) across the UK. The research population is therefore very large and diverse. According to Rea and Parker (1997), there is no better method of research than a survey for collecting information about large populations. Surveys are also viewed as the most appropriate method of studying participants' behaviour and job perceptions (Mintzberg, 1973; Rea and Parker, 1997). Moreover, survey research

strategy makes it possible to generalize the results to the research population while enabling comparisons between target groups to be made (Burns, 2000). In this study, differences in experiences and attitudes within and across contractors, owners and their Architects/Engineers were of particular interest.

There are two main types of surveys: cross-sectional and longitudinal studies. In a cross-sectional survey, data is collected on relevant variables at the same time or within a relatively short space of time. Longitudinal surveys on the other hand involve collecting data over long periods of time by taking measurements of the variables over two or more distinct periods. This type of survey was eliminated as inappropriate in the light of the time and resource constraints within which the research had to be completed, leaving cross-sectional survey as the most appropriate.

The methods for obtaining survey data are (Rea and Parker, 1997; Burns, 2000; Creswell, 2003): (1) sending a questionnaire out by post, fax or internet for the respondents to self-administer; (2) using an interviewer to administer the questionnaire either by face to face or telephone interviews. The second option was eliminated as unsuitable on account of fragmentation of functional roles involved in DDA and geographical dispersion of the participants. Considering the first option, fax and internet were discarded on account of their poor response rate (Rea and Parker, 1997; Burns, 2000) leaving postal questionnaire survey as the most appropriate.

2.3 Literature Review

The importance of carrying out a review of literature has been emphasized by authors such as Gall *et al*. (1996) and Fellows and Liu (2003) as follows:

compare the research idea to existing knowledge in the chosen field;

to provide insight to whether the research is viable;

to provide insight to whether the research addresses a topical issue and will also not lead to repetition;

to help redefine the research topic to reflect current trends in the chosen field;

to help develop an appropriate methodology for undertaken the research;

identify and /or suggest routes with regard to advancing knowledge;

help generate other ideas;

to assist in further refinement of the research questions and objectives.

Therefore the first stage of the research methodology concerned a comprehensive review of literature relating to DD analysis. The objective of the review was to provide the background and context upon which the research was to be established. The review covered a wide range of issues including: (i) the theoretical and legal principles underpinning DD claims resolutions (reported in Chapter 3); (ii) planning and programming issues affecting DDA (Chapter 4); and (iii) existing methodologies for analysing DD claims (Chapter 5). The findings of the literature review formed the basis of the subsequent field surveys.

2.4 Design of the survey questionnaire

As mentioned in section 2.2, the questionnaire survey purports to answer the 'what' and 'which' questions in exploring the current use of DD analysis methodologies in the UK. The survey was designed carefully to ensure that it elicits useful responses to these questions and also overcome the limitations of postal questionnaire surveys.

This was achieved by following recommended best practice advocated in the literature by, for example, Moser and Kaltron (1986), Oppenheim (1992), De Vaus (2002) and Baker (2003). Such practice includes making sure the questionnaire is easy to read and understand, as short as possible and capable of completing within a matter of minutes, and organised to flow smoothly without any hidden bias. Also, the wording of the questions was carefully considered to prevent as far as possible any confusion or ambiguity.

In view of the nature of feedbacks being solicited, it was resolved that the questionnaire be designed to contain both open-ended and closed-ended questions. Each of these formats has distinct advantages and disadvantage so combining them was essential in reducing or eliminating the disadvantages of each whilst gaining their advantages. The questionnaire therefore consisted of multiple choice questions requiring ticked-box responses and open–ended questions. Provisions were also made for respondents to contribute in free text forms any further comments or views they have in respect of each questions.

According to Weisberg *et al.* (1996), questionnaire construction is really an art, much of which is learnt through practice and that it is so difficult that researchers rarely use a questionnaire in a survey without first pretesting it. Therefore, after series of reviews of the draft questionnaire, a decision was made to pilot the questionnaire before developing the final versions. In a pilot survey of acknowledged DD analysis experts in the UK and the US, twenty practitioners, were asked to comment on the questionnaire with regards to its clarity and the practicality of its completion by respondents. The response and comments received from eight of them were reviewed

and a number of revisions involving deleting, adding or rewriting questions made to the questionnaire for developing the final version of the questionnaire. A copy of the final version of the questionnaire is indicated in Appendix A.

2.5 Sampling

The absence of a specific sampling frame of construction organisations with experience of DD claims dictated use of non-probability sampling techniques. The *Kompass Register* (Kompass 2006), *NCE Consultants' file* (NCE, 2006), and *2002 RICS Directory* (RICS, 2002), which together lists in excess of 5000 providers of products and services in industry, was the starting point of sampling. A list of 2000 construction organisations of different sizes was first compiled from these sources. The list was then divided into the six geographical regions of the UK (North East, North West, South East, South West, Midlands and Scotland). Using a combination of quota and purposive sampling as described typically by Patton (1990) and Barnet (1991), 600 construction organisations (300 contractors and 300 consultants) were finally selected based on a need to ensure that the outcomes are nationally applicable and cover the experiences and attitudes of contractors as well as consultants, especially engineers and architects in their roles as contract administrators.

2.6 Data Collection

The questionnaires were addressed to the managing directors of the selected firms with an accompanying cover letter, explaining the purpose of the survey and asking that senior staff members with major involvement in claims preparation or assessment be encouraged to complete it. A sample of the cover letter is indicated in Appendix A.

The questionnaire was designed to produce answers to a number of questions pertinent to the research objectives outlined in section 2.2. This include the rating of existing DD analysis methodologies on a 5-point Likert scale in respect of: the extent of awareness, use and perceptions on reliability of these methodologies; the level of importance of a number of factors that influence the selection of DAMs; and the frequency by which a number of factors have been obstacles to the use of these methodologies in practice. This type of rating scale is recognised as the most appropriate for obtaining information about respondents' attitudes and perceptions or analysing particular attributes, as compared to asking a long list of individual questions (Rea and Parker, 1997; Baker, 2003).

Although the variables to be rated were identified from a thorough review on the body of literature on DD and subsequently a pilot survey, respondents were also invited to add any other methodologies or factors that they consider were important but not included in the questionnaire.

Considering the numerous terminologies by which existing DAMs are known by practitioners, there was a considerable risk that responses concerning the methods may be incorrectly answered. This problem was addressed by including, as an appendix to the questionnaire, a glossary of DAMs for the respondents' reference.

2.7 Data Analysis

The data obtained from the survey were ordinal in nature as most of the responses were ratings measured on the Likert scale. Such data cannot be treated using parametric statistics methods unless precarious and, perhaps, unrealistic assumptions

are made about the underlying distributions (Siegel and Castellan Jr., 1988, p.35). It was therefore found appropriate to analyze it using non-parametric statistics involving descriptive statistics analysis, relative index analysis, Kendall's Concordance, Spearman Rank Order Correlation test, Chi-square tests and Factor analysis. In all these, the *Statistical Package for the Social Sciences (SPSS)* and *Microsoft Excel* for Windows application software package were employed.

2.7.1 Descriptive statistics analysis

This involved the use of frequencies, percentages and means for presenting description finding of the survey. These techniques were employed for analysing data related to the characteristics of the respondents, their organisations, and open ended questions/comments. They were also used for the initial analysis of rating score data of the various research variables. Graphical techniques utilised for presenting the results from these analyses include pie chart, bar chart and tables.

2.7.2 Relative index analysis

This technique was utilised to further analyse responses related to ratings of the research variables. The technique has been used extensively in similar types of surveys and is recognised as an excellent approach for aggregating the scores of the variables rated on an ordinal scale by respondents (Holt, 1997).

The SPSS was first used to determine the valid percentage ratings (frequencies) of the variables rated, which were then feed into Equation (1) to calculate the variables' respective rank indices (RIs).

$$\mathrm{RI} = \left[\sum_{i=1}^{i=5} w_i f_i \right] \times \frac{100\%}{n} \qquad \text{---} \qquad (1)$$

where f_i is the frequency of response; w_i is the weight for each rating (given by rating in the measurement scale divided by number of points in it, which is 5 in this case); and n is the total number of responses. The ranking index is labelled differently depending upon the context, e.g., "involvement index", "awareness index", "success index", and "challenge index".

2.7.3 Kendall Coefficient of Concordance and Chi-square tests

To determine the degree of agreement among the respondents in their rankings, Kendall's coefficient of concordance (W) was used. This coefficient provides a measure of agreement between respondents within a survey on a scale of zero to one, with '0' indicating no agreement and '1' indicating perfect agreement or concordance. Using the rankings by each respondent, W was computed using Equation (2) below (Siegel and Castellan Jr., 1988, p. 265).

$$W = \frac{12 \sum R_i^2 - 3k^2 N(N+1)^2}{k^2 N(N^2 - 1) - k \sum T_j} \qquad \text{---(2),}$$

where $\sum R_i^2$ is the sum of the squared sums of ranks for each of the N objects being ranked; k is the number of sets of rankings i.e. the number of respondents; and T_j is the correction factor required for the jth set of ranks for tied observations given by $T_j = \sum_{i=1}^{g_j} \left(t_i^3 - t_i \right)$, where t_i is the number of tied ranks in the ith grouping of ties, and g_j is the number of groups of ties in the jth set of ranks.

To verify that the degree of agreement did not occur by chance, the significance of W was tested, the null hypothesis being perfect disagreement. The Chi-square (χ^2) approximation of the sampling distribution given by Equation (3) with (N-1) degrees of freedom is used for testing this hypothesis at a given level, for N>7 (Siegel and Castellan Jr. 1988, p. 269). Calculated χ^2 value greater than its counterpart table value implies that the W was significant at the given level of significance and as such the null hypothesis is not supported and thus has to be rejected.

$$\chi^2 = k(N-1)W \qquad \text{---} \ (3)$$

2.7.4 Spearman Rank Order Correlation test

Further analysis was performed to identify any relationship between "awareness" and "use" for each of the DD analysis methodologies on the one hand, and the "success" and "challenge" rate associated with claims analysed by the methodologies on the other. This correlation was performed using Spearman Rank order Correlation test, with the help of SPSS.

2.7.5 Factor analysis

In the absence of any standard lists of DAM selection factors, there was a considerable risk of the analysis of the responses yielding diverse results. Thus, in establishing the list of factors, it was considered important to ensure that the factors are of adequate relevance and were also independent. The response was therefore further analysed by grouping them using factor analysis.

The appropriateness of employing factor analysis was first confirmed by a number of tests including Kaiser-Meyer-Olkin (KMO), measure of sampling adequacy and Bartlett test of sphericity (see Appendix B for test results). Principal component analysis was then employed to extract six group factors with eigenvalues greater than 1, suppressing all other factors with eigenvalues less than 1 based on Kaiser's criterion (Kim and Mueller, 1994; Field, 2000, p.437). To clarify the factor pattern so as to ensure that each variable loads high on one group factor and very minimal on all other group factors, the variables were 'rotated' using varimax orthogonal rotation method.

2.8 Design of Interviews

The analysis of the results of the questionnaire survey revealed several issues, mostly related to programming matters, which pointed to the need for their further in-depth investigation to fully understand the current problems associated with DD analysis. This investigation was aimed at answering the 'how' and 'why' questions of the research, which cannot be satisfactorily answered through postal surveys; for example, why are the more reliable methodologies not popular?, how can DD analysis practice be improved?, According to Yin (1994), such questions require the adoption of qualitative research inquiry approach involving the use of in-depth interviews, experiments, history and case study for collecting the required information. These methods provide a deeper comprehension of the phenomenon being investigated as they require the investigator spending considerable length of time gathering information in the natural setting. It became clear that experiments, history and case study were not favourable for this research given the confidential nature of the issues being investigated in claims and difficulty of finding organisations willing to

cooperate in this regard. This leaves interviews as the most favourable option to use. Although there are various methods for administering interviews, the most pervasive one in qualitative studies is personal or face-face interviews as it allows observations to be made and also enables the researcher to interact with the natural setting (Creswell, 1994; 2003).

The format of questions asked in interviews can be classified in four ways (Patton, 1990; Bogdan, and Biklen, 1992): totally structured; structured questions with open responses (semi-structured); open questions with structured answers; and totally unstructured. The nature and scope of the issues to be investigated by the interviews suggested the second format, i.e. structured open-ended, as the most appropriate option for designing the interview questionnaire. This format allows interviewees to give the responses they thought were right thereby minimising bias that is often associated with closed–ended interviews. It also makes it possible for pursuing and probing for relevant information to help clarify some of the responses in some instances (Patton, 1990; Creswell, 2007).

The interviewees were required to provide information on specific questions related to the development of construction programmes and their maintenance, in order to well appreciate the problems affecting DD analysis. The questionnaire for this was designed following recommended approaches highlighted by authors such as Bogdan and Biklen (1992), Rossman and Rallis (1998) and Creswell (2007), to ensure that the questions are appropriate and well presented. The questionnaire comprised of two main sections: preconstruction stage programming and construction stage programming approach (a copy of the questionnaire is shown in Appendix C).

The potential interviewees were identified from the list of respondents who participated to the initial survey. This was achieved by asking them in the survey to indicate their willingness to grant further interviews to solicit their opinions on certain programming matters informed by the survey. Those who responded positively to this request were individuals in key positions within construction firms with considerable experience in DD analysis and programming of construction works. Their prior involvement in the survey also makes them highly suitable for the interview as they were aware of the framework of this research.

2.9 Interview data collection

Following the design of the questionnaire, the interviewees were contacted via telephone to arrange for appropriate interview date, time and place. Closer to the interviews, copies of the interview questionnaires were posted to the interviewees with an accompanying cover letter, reminding them of the time and date for the interview.

For each interview, interviewees were first briefed on the purpose of the interview and its expected duration. They were also assured that information received will be kept strictly confidential and their consent further sought on note taking by writing and tape recording. In the course of the interviews, a number of steps were taken, to ensure its proper conduct and avoid any possible biases from creeping in, including (Patton, 1990): (i) asking one question at a time; (ii) remaining neutral as far possible by trying not to show strong emotional reactions to responses, for instance; and (iii) taking control of the interview by sticking closely to questions of interest.

Generally, each interview took between 1-2 hours to complete, where information was recorded by both note taking and tape recording. This recording was important for the purpose of making future reference to the data in the same detail as was recorded in order to fully appreciate everything that was discussed. The data obtained was later transcribed and analysed (refer to Chapter 7 for results).

2.10 Best practice recommendations

Information gathered from the literature review, the survey and the subsequent interviews was used to draw deductions and conclusions in respect of the research objectives. A number of best practice recommendations were then proposed as a framework for improving DD analysis practice (see Chapter 10).

2.11 A model for selecting appropriate DAM

In addition to the recommendations, a particular problem area was isolated for further consideration, namely: *The decision to select any of the myriad methodologies available for analysing delays in any claims situation requires careful consideration of a number of criteria but there is no decision aids available for analysts to rely on to ensure a more objective selection process.* To redress this, a model for selecting an appropriate methodology for analysing delay claims was developed. This model is mainly based on scoring competing DAMs on 18 selection criteria identified as relevant from the literature review and the questionnaire survey. Employing a multiattribute technique, an aggregate score for each of the methodology is computed reflecting their respective suitability to use for the analysis of the claims at hand. Detailed description of the model is reported in Chapter 8. Model validation is essential part of model development process if models are to be accepted and used to

support decision making (Macal, 2005). The model was therefore validated via experts' review using survey. The rationale for adopting this validation technique, the process involved and the results obtained are reported in Chapter 9.

2.12 Summary

This chapter has presented an outline of the research methodology adopted for carrying out this research. A combination of qualitative and quantitative research methods was utilised. This involved first, a comprehensive literature review followed by a pilot survey for fine-tuning the questionnaires for a subsequent nation-wide survey of construction and consulting organisations to explore the current use of existing DD analysis methodologies and associated problems. These problems were then investigated in much depth using semi-structured interviews with some of the respondents who participated in the initial survey. The data collected was analysed, with the aid of SPSS and Excel, using a variety of statistical methods including descriptive statistics, relative index analysis, Kendall's Concordance, Chi-square test, Spearman Rank Order Correlation test and Factor analysis.

Information gathered from literature review, the survey and subsequent interviews was used to: draw deductions and conclusions in respect of the research objectives; propose a number of good practice recommendations for improving DD analysis; and developed a model for selecting appropriate DAM. This model was validated via experts' review through survey.

CHAPTER THREE

3 THEORETICAL CONCEPTS AND LEGAL PRINCIPLES GOVERNING DD CLAIMS RESOLUTIONS

3.1 Introduction

The importance of time to construction contracting parties as highlighted in Chapter One has made it necessary for employers to specify in their contracts the time for performance, often in terms of either a final date or an overall period for completion. However, a number of factors including the performance of the parties affect the actual project duration causing the project to suffer time and/or cost overruns. To recover such losses, claims often arise in several ways, the commonest being claims by contractors against employers for extensions of time and/or for loss and expense. The resolution of such claims involves claimants/defendants identifying and quantifying the effects of one or more occurrence that caused (Pickavance, 2005):

delay to progress that caused the delay to one or more completion dates;

prolongation of contractor's and/or subcontractor's time-related costs;

delay to progress that caused loss and/or expense to be suffered by contractors or subcontractors; and

reduction in productivity (or disruption) that caused loss and/or expense to be suffered by contractors and/or subcontractors;

Employers and contractors often resort to various methodologies in undertaking this task as highlighted in Section 1.2. There are two main categories of such methodologies referred-to in this thesis as: "Delay Analysis Methodology" (DAM) and "Disruption Analysis Methodology" (DSAM). For proper understanding of the

use of these methodologies, this chapter provides an overview of the accepted legal and theoretical concepts that influences DD claims resolution. The review was based on general research papers on DD analysis and UK cases, although some concepts based on US cases were considered for reference purposes. The relevant issues reviewed include:

- types of delays;
- the resolution of concurrent delays;
- float ownership;
- resolving delays when programme shows early completion;
- delays experienced after completion date; and
- the requirements for the production or assessment of DD claims.

The findings of this review and those of the next two chapters formed the basis of the subsequent field surveys and the proposed recommendations for promoting good practice.

3.2 Types of delay

The term "delay" in construction contracts has no precise technical meaning. It can be used in different sense to mean different conditions in project execution (see for example, Pickavance, 2005, p. 8). However, the term is often used in its basic sense to mean any occurrences or events that extend the duration or delay the start or finish of any of the activities of a project. Delays therefore increase the time and cost allocated for executing the various project activities, resulting in project cost overruns and late completions. The latter effect will only occur when the delay lies on the critical path of the programme.

Delayed completion of projects is generally caused by the actions or inactions of the project parties including the employer, contractor, subcontractors, project designers/ supervisors and neither of these parties (e.g. acts of God). Based on these sources and the contractual risk allocation for delay-causing events, three main categories of delays are generally recognised: excusable, nonexcusable and compensable delays.

Excusable delays are those against which the contractor is entitled to extension of time under the terms of the contract. The contractor is said to be 'excused' liability for liquidated damages for the period of the extension which otherwise would have been payable to the employer. An excusable delay is therefore one for which the employer is generally responsible although some excusable delays are outside the control of employers, e.g. exceptionally adverse weather conditions. Compensability concerns the issue of whether the contractor is entitled to extra payment on account of the delay. Thus, a compensable delay is one for which the contractor is entitled to such payment. There is generally no such entitlement for delay caused by events over which the contractor exercises some control, e.g., productivity of its labour or equipment.

Whether a delay is excusable or compensable is a matter of the allocation of risk between the contractor and the employer, as defined in the contract based on a number of principles (Smith, 1995). Generally, the risks of project delays from events over which the employer has control or for which he is responsible are usually allocated to the employer. For such delays, the contractor is entitled to time extensions and recovery of extra cost consequential upon the delay; and are often referred to as "excusable compensable" (EC) delays. Examples include ordering variations and

additional work and late supply of necessary information to the contractor. The risk of delays from events over which neither party has control, e.g. acts of God and strikes, are usually shared. The contractor is usually entitled to extension of time but not recovery of additional payment. Thus, the employer forfeits entitlement to recover delay damages from the contractor. This type of delay is referred to as "excusable non-compensable" (EN) delay.

The contractor usually assumes the risks of costs and consequences of delay events which are within its control e.g. shortage of staff or equipment, late mobilisation, etc. This type of delay is referred to as "nonexcusable-noncompensable" (NN) delay, which could be compensated to the employer in the form of liquidated or actual damages paid by the contractor for late completion.

It is important to note that the terms compensable, excusable and non excusable are from the perspective of the contractor. Thus a delay that is compensable is compensable to the contractor but non-excusable to the employer. On the other hand, a delay deemed non-excusable non compensable is compensable to the employer because it results in levying of liquidated damages.

Delays are also distinguished between "critical" and "non-critical" delays. The former are those that cause delay to project completion date whilst the latter affect progress but not overall completion. Most contracts require that in order for delay to warrant an extension of contract time, it must affect the completion of the project (i.e. the delay must be critical). This provides the basis for the high importance attached to the use of critical path method (CPM) of scheduling for proving or disproving time-

related claims such as extension of time and prolongation cost (Wickwire *et al*. 1989; Kallo 1996b; Bramble and Callahan, 2000).

The terms "independent delays", "serial delays" and "concurrent delays" are also used to describe delays based on the interrelation of the above delay types with respect to their duration and time of occurrence. Independent delays are delays that occur in isolation or without other consecutive or simultaneous delays while serial delays occur in sequence consecutively and not overlapping with each other on a particular network path. On the other hand, two or more delays in which their time of occurrence or effects overlaps are often termed "concurrent delays". As a summary, Figure 3.1 classifies the different types of delays based on their various attributes.

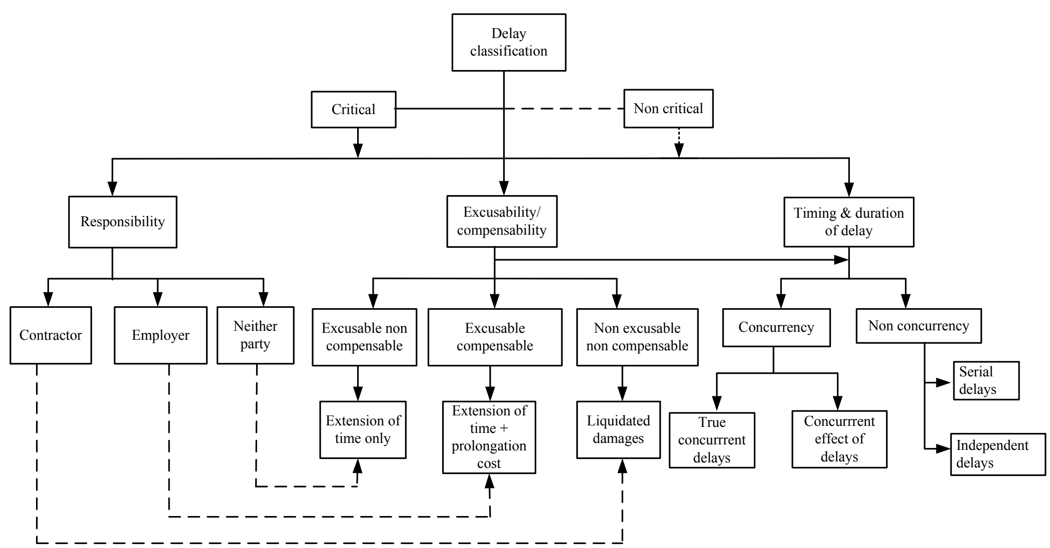

Figure 3.1 Delay Classifications

Independent and serial delays are relatively easy to resolve compared to concurrent delays. The concept of concurrent delays has thus been the subject of much discussions and debate among researchers and practitioners. It therefore deserves further review.

3.2.1 Concurrent delays

The resolution of this type of delay has been a contentious legal and technical subject in construction and engineering contracts (SCL, 2002). The reason for this is largely due to the fact that resolving it requires the consideration of the interaction of different factors such as the time of occurrence of the delays, their length of duration, their critically, the legal principles of causation and float ownership (Arditi and Robinson, 1995; Bubshait and Cunningham, 2004; Ostrowski and Midgette, 2006). Its resolutions also require the consideration of defensive views of the parties involved, such as argument over concurrent delays as delay-pacings strategy (Zack, 2000). The situation is made worst by the lack of uniformly accepted definition among practitioners as to what concurrent delays means in the first place (SCL, 2002).

Rubin *et al.* (1983) defined concurrent delays as the situation in which two or more delays occur at the same time either of which had it occurred alone, would have affected the ultimate completion date. It means each of the delays must independently affect the critical path. Some argue that to be considered concurrent delays, the delays need not commence precisely at the same time (for e.g. Reynolds and Revay, 2001). There is the view also that the delays need not occur in the same activity on the same critical path but may exist in different activities on parallel critical path as well (Ponce de Leon, 1987; Arditi and Robinson, 1995). The *SCL Protocol* (SCL, 2002) defines a

true concurrent delay as *"the occurrences of the delays, one an employer risk event and the other a contractor risk event, at the same time, and their effects felt at the same time"*. This occurrence is, however, extremely rare in practice since time is infinitely divisible. For instance, two delay events occurring on the same day would not necessarily be true concurrent delays because one may have occurred in the morning while the other in the afternoon. Concurrent delay is also somewhat misleadingly used to refer to the occurrence of two or more delay events at different times but their effect are felt (in whole or in part) at the same time. To avoid confusion, this is termed "concurrent effect" of sequential delay events (SCL, 2002).

To clarify the above definitions, various scenarios of concurrent delays illustrating these definitions are shown in Figure 3.2.

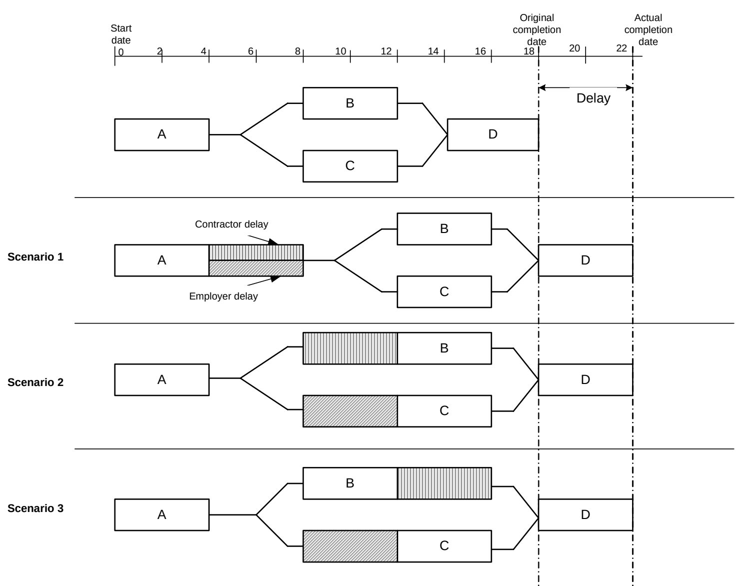

Figure 3.2 Different scenarios that define Concurrent delays

The figure shows a project of 4 activities (A, B, C and D), suffering a 4-weeks project delay, which was caused by employer and contractor delays each lasting 4 weeks.

Scenario 1 is where both delays, starting and ending at the same, affect a single activity on the same critical path. In scenario 2, both delays affect different activities on different critical paths but start and end at the same time. Scenario 3 is similar to scenario 2 except that both delay start and end at different times.

3.2.2 Concurrent Delay Types and their Remedies

The major challenge with concurrent delays rests with allocating the responsibilities for the overall project delay. This challenge does not lie with concurrent delay situations of two or more delays of the same kind (i.e. from the same party) but those of different delay types (e.g. employer delay and contractor delay). Different delay types can be combined to give four main categories of concurrent delays as follows (Kraiem and Diekmann, 1987):

excusable non-compensable delay and nonexcusable non-compensable delay.

excusable non-compensable delay and excusable compensable delay

excusable non-compensable delay, nonexcusable non-compensable delay and excusable compensable delay

nonexcusable non-compensable delay and excusable compensable delay

Determining which remedy (time extensions and/or delay damages) to be accessed by the parties for these concurrent situations is one of the much contested issues. Four main approaches for determining such remedies have been reported in the literature as (Marrin, 2002): First cause defines liability, dominant cause approach, the American approach and the “Malmaison” Test.

First cause defines liability

This approach argues that liability must rest with the party responsible for the first delay encountered and that subsequent delays occurring during the period of the first delay should not affect liability. For example, assume that an activity on a critical path is being delayed by an adverse weather condition and in the course of this delay, an activity on a parallel critical path begins to experience delay as a result of poor planning on the part of the contractor. If this second delay ends before that of the first then the main cause of the project delay would be attributed to the first delay. The philosophy behind this approach is that once the job is stopped by one cause of delay, it cannot be any more stopped by another delay, unless and until the second delay continues after the first delay has ceased (Scott, 1993b). The main weakness of this approach is that it does not provide solution for situations where all the delays begin at the same time. Furthermore, the approach would be inapplicable to concurrent delay situation arising from consecutive delays with little, if any, overlap.

This first-in-time principle of resolving causation in concurrent delays seems to operate based on the 'but for' test. By this test, a party seeks to lay responsibility for project delay on the other party by arguing that the delay would not have occurred but for the latter's actions or inactions which occurred first. Although such argument are often made there appear to be no reported English case that lends support to its use. Their application in a number of cases has received unsympathetic receptions making it an approach that no longer has a wider appeal (Marrin, 2002).

Dominant cause approach

According to this approach, the claimant may recover its damages if it can establish that the delay for which the defendant must assume responsibility is the overriding or

the 'dominant' cause of the loss suffered. Which cause is dominate is a question of fact which is not solved by the mere point of order in time, but is to be decided by applying common sense standards (Furst, 2006). This approach was given support in the recent case of *John Doyle Construction Ltd v Laing Management (Scotland) Ltd, (2004) BLR 295.* Paragraph 15 of the judgement in respect of apportionment of loss and expense in situations of concurrent delay is as follows:

> *"…….In the second place, the question of causation must be treated by 'the application of common sense to the logical principles of causation'………In this connection, it is frequently possible to say that an item of loss has been caused by a particular event notwithstanding that other events played a part in its occurrence. In such cases, if an event or events for which the employer is responsible can be described as the dominant cause of an item of loss, that will be sufficient to establish liability, notwithstanding the existence of other causes that are to some degree at least concurrent………….If an item of loss results from concurrent causes, and one of those causes can be identified as the proximate or dominant cause of the loss, it will be treated as the operative cause, and the person responsible for it will be responsible for the loss."*

However, in the case of *H. Fairweather and Co. Ltd v London Borough of Wandsworth (1987) 38 BLR 106,* the court considered *obiter* that this approach was not correct and that each separate cause of delay should be assessed on its own individual merits. Another weakness of this approach is the common sense criterion relied on which could result in unfair apportionment, particularly where the competing causes are of approximate equal causative potency. Additionally, the approach may not suffice on projects that sustained multiple overlapping changes or delays with long durations because of all the assumptions that must be made regarding the remaining durations of activities being affected (Reynolds and Revay, 2001).

<u>The American approach</u>

Based on US case law, the general view on concurrent delays in which the employer and the contractor are both responsible for delays to project completion, is that neither

party will recover financial recompense unless and to the extent that they can segregate delay associated with each competing cause (Marrin, 2002). Kraiem and Diekmann (1987) somehow described this view as the 'easy rule' and 'fair rule' (see Table 3.1).

Table 3.1 Remedies for concurrent delays (Kraiem and Diekmann 1987)

Concurrent delay type	**Remedy (for critical path)**	
Any delay concurrent with excusable non compensable	Time extension	
	Easy rule	*Fair rule*
Excusable compensable concurrent with non excusable non compensable	Time extension	Apportionment

Marrin (2002) has criticised this approach as not likely to work well in contracts where the contract administrator is given some discretion in dealing with contractors' claims such as in JCT contracts. He argued that as a result of such discretion, there is the possibility of the employer recovering liquidated damages even when the proof of contractor's default as the sole cause of the delay is not possible.

The "Malmaison" Test

The issue of responsibility for project delay resulting from two concurrent delays was a fundamental issue in the recent case of *Henry Boot construction (UK) Ltd v Malmaison Hotel (Manchester) Ltd (1999) 70 Con L.R. 32*. This case relates to a dispute on pleadings in an arbitration regarding one of the contractor's extensions of time claims. In his judgement, HHJ Dyson J stated certain areas of common ground that had been agreed between the parties including:

> *"……. it is agreed that if there are two concurrent causes of delay, one of the which is a Relevant Event, and the other is not, then the contractor is entitled to an extension of time for the period of delay caused by the Relevant Event notwithstanding the concurrent effect of the other event."*

The view purported by this case is that provided one of the causes of delay in any given concurrency situation affords grounds for extension of time under the contract, then the contractor should be given time extension notwithstanding any default on his part. This is quite similar to the American approach on the aspect of time extensions entitlement. The approach sounds reasonable and just in the sense that denying the contractor time extension in such circumstances could make him liable to the payment of liquidated damages even though the project would have been delayed anyway due to employer's default. This denial of time extension conflicts with the prevention principle that "a person asking another to do something cannot insist upon a condition if it is his own fault that the condition has not been fulfilled" (see *Amalgamated Building Contractors Ltd v Waltham Holy Cross UDC (1952) All ER 452 at 455*).

The approach was considered and afforded support by HHJ Seymour Q. C. in the more recent case of *The Royal Brompton Hospital NHS Trust v Hammond (No. 7) (2001) 76 Con L.R. 148*:

> *"However, if Taylor Woodrow was delayed in completing the works both by matters for which it bore the contractual risk and by Relevant Events, within the meaning of that term in the Standard Form, in light of the authorise to which I have referred, it would be entitled to extensions of time by reason of the occurrence of the Relevant events not withstanding its own defaults."*

A slight departure from the Malmaison case arose in the case of *Motherwell Bridge Construction Ltd v Micafil Vakuumtechnik (2002) 81 Con L.R. 44*, where the Judge stated that it is necessary to apply a test of common sense and fairness in deciding matters of extensions of time involving issues of concurrency. He considered that a full extension of time should be awarded where there is concurrent contractor-caused and employer-caused delay, if it is fair and reasonable to do so. Earlier cases supporting this view suggest that the approach is not new. Cases such as *Peak*

Construction (Liverpool) Ltd v McKinney Foundations Ltd (1970) 1 BLR 111 and *Rapid Building Group Ltd v Ealing Family Housing Association Ltd (1984) 29 BLR 5* suggest that if the separation of delays caused by the employer from those which are the contractor's own fault is impossible to achieve, then the contractor must be given the benefit of the doubt in regard to an extension of time. Also in *Walter Lawrence and Son Ltd v Commercial Union Properties (UK) Ltd (1984) 4 Con. L.R. 37*, in which the Architect challenged the contractor's time extension claim on the basis of the occurrence of contractor concurrent delay, the court ruled the Architect's view as erroneous. The ruling was that the contractor was entitled to an extension of time in respect of the inclement weather which occurred irrespective of whether or not the contractor was at that time in culpable delay.

The Malmaison approach also appears to be favoured by claims professionals in the UK as evident by a recent survey (Scott and Harris, 2004), making it an approach with a wider appeal. Not surprisingly, the *SCL Protocol* (SCL, 2002) adopted it stating on page 15 of the document that:

> *"where contractor delay to completion occurs concurrently with employer delay to completion, the contractor's concurrent delay should not reduce any extension of time due".*

This approach, however, does not appear to deal specifically with the entitlement to loss and expense. The view of the *SCL Protocol* on this is that:

> *"If the contractor incurs additional costs that are caused both by Employer Delay and concurrent Contractor Delay, then the contractor should only recover compensation to the extent it is able to separately identify the additional costs caused by the employer Delay from those caused by the Contractor Delay."*

This view is similar to the American approach and received support in the *Laing* case as indicated by paragraph 16 of its judgement:

> *"In the third place, even if it cannot be said that events for which the employer is responsible are the dominant cause of the loss, it may be possible to apportion the loss between the causes for which the employer is responsible and other causes. In such a case it is obviously necessary that the event or events for which the employer is responsible should be a material cause of the loss. Provided that condition is met, however, we are of opinion that apportionment of loss between the different causes is possible in an appropriate case. Such a procedure may be appropriate in a case where the causes of the loss are truly concurrent, in the sense that both operate together at the same time to produce a single consequence."*

However, the survey by Scott and Harris (2004) suggests that practitioners have different view on this. The majority of the respondents in this survey felt that contractors should be entitled to cost compensation for employer caused delays concurrent with contractor caused delays. Similar views were expressed by majority in an earlier study by Scott (1993a).

It is clear from the foregoing that there is currently no consensus as to the resolution of concurrent delays responsibilities. This suggests that there is still more to do in order that concurrent delays can be resolved with fewer chances of disputes. Another contentious matter that contributes to this problem is the issue of float and its ownership.

3.3 Float

The concept of float in projects is often associated with critical path type schedules. The term "float" is used to refer to the time assigned to an activity, which is longer than the shortest time that is reasonably necessary to undertake that activity. It can also be used in the alternative sense of the length of time before an activity becomes on (or very close to) the critical path (see for e.g. *Mirant Asia-Pacific Construction (Hong Kong) Ltd v Ove Arup Partners International Ltd (2007) EWHC918 (TCC)*). As an example to illustrate this, an activity is said to have 3 days of float if that activity has say 10 days available to it to be completed although the activity will

actually require 7 days of work. The start or finish date of this activity could therefore be delayed up to 3 days without delaying the project completion date. The unit of measurement of float can be days, weeks or months depending on the unit of planning of the project. Whilst there are various types of floats, total float as described above is of most importance in the resolution of DD claims.

Float is a valuable resource to both employers and contractors as they tend to rely on it for planning and control purposes. Typically, it offers flexibility to contractors in the arrangement and performance of non-critical activities, as a means of making good delays on the critical path. Employers on the other hand, often see it as an opportunity to make changes since it can accommodate the impact of such changes. For these reasons, a situation can easily be envisaged where an employer's changes causes a delay such that the majority of float on a particular activity is consumed making it a near critical activity. As such, any subsequent contractor-caused delay to this activity will force it to become critical and delays the project. In this situation, the contractor is unlikely to get an extension of time but rather would be liable to liquidated damages. Contractors often have difficulty accepting this, arguing that had the employer's delay not occurred, its delay would not have caused the delay to the project. Whether the contractor's argument is valid or not is a question of who owns the float that was consumed by the employer's delay. The answer to this question tends to influence the results of delay analysis (Arditi and Pattanakitchamroon, 2006).

Float ownership has thus been a highly debateable issue which has long exercised the attention of researchers and other writers. McDonald and Baldwin (1989) proposed

three main categories of float ownership: float belongs to the contractor, float belongs to the project; and float belongs to either party so long as it is reasonably utilised.

3.3.1 *Float belongs to the contractor*

This appears to be the traditional view. Earlier authors such as Wickwire and Smith (1974), Fondahl (1975), Antill and Woodhead (1982) and De la Garza *et al*. (1991) held this view on the basis that the float is an aspect of the contractor's programme and so it should be up to him how he constructs the project. De la Garza *et al*. (1991) added that float should be traded as a commodity and that the contractor is entitled to sell the float in case the owner needs it. Claims practitioners in the UK appear to be in supportive of contractors owning float, as the survey of Harris and Scott (2001) suggests. However, a major criticism on this relates to the likelihood of some aggressive contractors taking the ownership matter to the extreme by contesting, for example, that in order to achieve equitable adjustment, they should receive an extension of time for any or all employer delays to allow for float restoration, irrespective of whether or not there has been a total delay to the project (Zack, 1993).

This form of ownership is also not likely to be accepted by the courts. For instance, in *Ascon Contracting Ltd v Alfred McAlpine Construction Isle of Man Ltd (1999) 66 Con L. R. 119*, the judge, in response to the contractor's (McAlpine) argument that the subcontractor (Ascon) cannot claim the benefit of float in the main contract and that it belongs to the contractor for use as he wishes, stated that:

> *"In my judgment that argument is misconceived. The float is certainly of value to the main contractor in the sense that delays of up to that total amount, however caused, can be accommodated without involving him in liability for liquidated damages to the employer or, ………..He cannot, however, while accepting that benefit as against the employer, claim against sub-contractors as if it did not exist. ……..*

No doubt those different situations can be described, in a sense, as ones in which the "benefit" of the float has accrued to the defaulting party or parties, but no-one could suppose that the main contractor has, or should have, any power to alter the result so as to shift that "benefit".

Another case that seems to undermine this type of float ownership is *Henry Boot v Malmaison*. In addressing the question of the effects of employer's risk event on project completion date, the judge stated that:

"………..In my view the employer is entitled to advance these other matters by way of defence to the extension of time claim. It is entitled to say (a) the alleged employer risk event was not likely to or did not cause delay e.g. because the items of work affected were not on the critical path, and (b) the true cause of the ………"

3.3.2 Float belongs to the project

Under this view, the project owns the float and may be used by whoever gets it first. Unlike most UK standard forms, most American standard contracts, particularly those of public procurements usually specify this approach as how float in the contractor's programme is to be dealt with (Blake and Aaron, 1986, Wickwire, *et al.,* 1989). This view is also supported by American courts, upholding that float is not for the exclusive benefit of any party to the project but should be available to either party on a 'first-come first-serve basis' (Wickwire, *et al.*, 1989). There is, however, very little UK cases relating to float with *Ascon v McAlpine* as the one that comes closest to supporting this position. The judge in this case rejected the contention that float belongs to the contractor and concluded (using an example) that if a number of contractors caused delay to a project they should equally share in the 'benefit' of any available float. Further support to this approach is offered by the *SCL Protocol* (SCL, 2002) which recommends this approach as the "fall back position" if float ownership is not specified in the contract. Its main drawback, however, lies in the fact that it

could lead to artificial scheduling on the part of some unscrupulous contractors, by showing all activities as critical, in an attempt to defend themselves (Zack, 1993).

3.3.3 Float belongs to either party so long as it is reasonably utilised

As a compromise between the above two approaches, the view here is that float belongs to either party and has to be used by the party having more reasonable basis for its use. This seems fairer than the above two approaches in that neither party is entitled to the exclusive control of float time nor can use it unreasonably on first come first serve basis. However, the use of this approach is likely to be contested in practice as the term “reasonableness” is vague in practical terms.

The issue of float ownership has also been tackled by a number of researchers. Ponce de Leon (1982) suggests a compromise approach in which float is to be allocated in a shared way. This sharing involves allocating a percentage of the total float available to a given path to each activity on that path based on their durations. In the event of an excusable delay that consumes an activity’s float beyond zero into negative, time extension may be justified to preserve the other activities’ floats in the approved schedule. Another compromise approach, proposed by Pasiphol and Popescu (1994), seeks to distribute total float to each activity based on some qualitative factors. However these factors are to be subjectively assessed and thus may be subject to manipulations.

Householder and Rutland (1990) suggests that float ownership should be based on the allocation of risk associated with the project cost, and that float should be owned by the party who loses or gains as a result of fluctuation in project cost. Thus contractors

should own float in fixed-price contract since they bear the ultimate risk of project cost whilst the owner should own it in cost-plus contracts for the same reason.

3.4 Early completion programmes

To avoid liquidated damages, contractors sometimes manage to programme the work to take up shorter working period than the accepted contractual period thereby finishing early. The surplus time between the early finish date and the contractual completion date is often termed "project float". However, the principle that time extensions or liquidated damages be awarded for only delays that affect completion date, poses two main questions on the right for the contractor to finish early:

(i) is the employer obliged to facilitate an earlier completion than the specified contractual completion date?

(ii) is the contractor entitled to time and cost compensations for employer–caused delays that prevent early completion, even though completion is not delayed beyond the contractual completion date?

The unresolved issue of float ownership has made it more difficult to resolve these questions. This first question was considered by a UK court in *Glenlion Construction Ltd* v *The Guinness Trust (1987) 39 BLR 89*. In this case, the contractor had prepared a programme showing completion of the works (in 101 weeks) before the contractual date for completion of 114 weeks. The court ruled that the contractor was entitled to complete on an earlier date, but the employer only has an obligation to provide information to achieve the actual date for completion, without deliberately hindering the contractor.

On the second question, Birkby and Brough (1993) argued that there is no need for time extensions as work has been completed within the contract period. Any payment of delay damages to the contractor in such circumstances has also been opposed on the basis that the contractor's early completion programme may be unreasonable. Zack (1993), for instance, suggests that contractors typically bid projects for the full time of performance and often discover after bid opening and award that the job can be accomplished in less time. Therefore to prevent the possibility of over-recovery of compensation by contractors or expose the contractor to the possibility of liquidated damages for failure to complete by the early completion date, certain proofs have to be satisfied by the contractor. These include establishing that: the contract was bid on an early completion basis, the work was managed to schedule, there was no concurrent contractor delay and the contract allowed time for completion to be reduced to the early completion date (Galloway and Nielsen, 1990; Zack, 1993). This question has also been considered by a number of US cases which suggest that the contractor may well have a case for compensation as long as the contractor's original plan can be proven to be reasonable and that he can show that he would have completed earlier 'but for' the employer's action or inactions (Wickwire *et al*., 1989). Although it appears the issue is yet to be considered by UK courts, the American view seem to be in agreement with that of UK professionals. In the surveys by Scott (1993a) and Scott and Harris (2004) on how UK professionals deal with claims, the majority of respondents were of the view that contractors should be awarded time extensions and paid overhead cost in situations of employers delaying contractors early completion. The view also concurs with the position taken by the *SCL Protocol* (SCL, 2002).

3.5 Delays experienced after completion date

Another issue of importance in DD claims is the occurrence of employer-caused delays after the expiry of contractual completion date when the contractor is in culpable delay. There have been some questions as to whether the Contract Administrator (e.g. Architect/Engineer) has the power to extent time or issue variations in such situations and how the delay assessment should be done. In the past, courts in the US resolved this matter in favour of contractors by awarding a per se time extension from the contract completion date to that date when the delay ends (Wickwire and Smith, 1974; Jentzen *et al.,* 1994). This approach, often termed "gross method", is supported by contractors by asserting the argument that since all project activities were showing negative floats as at the time of occurrence of the employer-delay it would be unreasonable to expect the contractor to complete the works before an event had occurred that delayed the completion date (Wickwire *et al.*, 1989). However, the concept of negative float, which maintains that activity path(s) with the lowest negative float value is the critical path, has in part, led to "turning the table" in favour of the employer by considering the "net effect" method. This method refers to the addition of the amount of time taken by the delay to the date upon which the contractor should have finished the work, be it the original or adjusted completion date, even though this may be well before the date upon which the change was ordered. This approach has received the favour of UK courts as evident in a number of cases. For instance, in the case of *Balfour Beatty Building v Chestermount Properties (1993) 62 BLR 1,* concerning a contract based on JCT 80*,* the court upheld the arbitrator's decision that the architect did have jurisdiction under Clause 25 to extent time and that only a "net" extension of time should be awarded. Earlier UK cases that offer support to this approach are *Amalgamated v Waltham (1952) All ER*

452 at 455 and *McAlpine Humberoak v McDermott International (1992) 58 BLR 1 at 55*. The judge in *Amalgamated* case cited an example that if a contractor is in culpable delay near the end of the work and a strike (neutral event) occurs and lasts for a month, then the contractor can get an extension of time for that month and nothing for the earlier delays caused by his own fault. In the case of *McAlpine,* the judge rejected the claimant's argument against the gross effect stating:

> *" Mr Thomas submits, that since the extra work is covered by the definition of the work in clause 1 of the contract, and since the extra work was not ordered until 11 June, the date for completion of the work cannot precede that date. Accordingly the defendants' claim for damages cannot run from 1st May.*
> *We do not agree… if a contractor is already a year late through his culpable fault, it would be absurd that the employer should lose his claim for unliquidated damages just because, at the last moment, he orders an extra coat of paint."*

3.6 Requirements for the production and assessment of DD claims

In dealing with projects DD, most standard forms of construction contract generally require the contractor to notify the Architect/Engineer of an event as soon as it becomes apparent that it has or may cause delay to the completion date and to provide an estimate of its or expected effect on the completion date. On receiving this claim, the Architect/Engineer is often required to act fairly and reasonably in its assessment. In both instances, there would always be some form of analysis required, either carried out contemporaneously or at some later point in order to determine what, if any, extension of time and/or money should be awarded.

The question now is what should be the accepted approach one should adopt in carrying out the analysis. A notable case that considered this issue is *McAlpine Humberoak Ltd v McDermott International (1992) 58 BLR 1*. McAlpine, engaged as a subcontractor by McDermott in respect of a North Sea oil rig project, claimed for delay damages as a result of a large number of drawings issued by his contractor. At

first instance, the Court of Appeal upheld that the contract had been frustrated by the number of drawings issued to the extent that the plaintiff was no longer under an obligation to complete within the contract period. This decision was overturned by the Court of Appeal and held that the plaintiff approach was simply theoretical and inappropriate, saying:

> *"When the Defendants' witnesses came to give evidence, they undertook the task which was never undertaken by the Plaintiffs, of tracing the impact of every drawing revision, VO and TQ…….The judge dismissed the Defendants' approach to the case as being a retrospective and dissectional reconstruction by expert evidence of events almost day by day, drawing by drawing, TQ by TQ and weld procedure by weld procedure, designed to show that the spate of additional drawings which descended on McAlpine virtually from the start of the work really had little retarding or disruptive effect on its progress. In our view the Defendants' approach is just what the case required."*

Also in *John Barker Construction Ltd v London Portman Hotel Ltd (1996) 83 BLR 31,* the way and manner contractors' DD claims assessment should be carried out was a fundamental issue. In this case, the court stated that:

> *"I accept that Mr. Miller believed, and believes, that he made a fair assessment of the extension of time due to the Plaintiffs. It is fairly apparent that the Defendants were concerned by the overrun of the contract in time and costs, and I have no doubt that Mr. Miller was conscious of this, but I believe also that he endeavoured to exercise his judgement independently. However, in my judgment his assessment of the extension of time due to the Plaintiffs was fundamentally flawed in a number of respects, namely:*
>
> 1. *Mr. Miller did not carry out a logical analysis in a methodical way of the impact which the relevant matters had or were likely to have on the Plaintiffs' planned programme.*
> 2. *He made an impressionistic, rather than a calculated, assessment of the time which he thought was reasonable for the various items individually and overall. (The Defendants themselves were aware of the nature of Mr. Miller's assessment, but decided against seeking to have any more detailed analysis of the Plaintiffs' claim carried out unless and until there was litigation)."*

This case was considered in the recent case of *Balfour Beatty Construction Limited v The Mayor and Burgess of the London Borough of Lambeth (2002) 1 BLR 288,* in

which the claimant sought to enforce an adjudicator's decision in relation to an extension of time and loss and expense claim. In this case, it was said by His Honour Judge Humphrey Lloyd QC that: *"In the context of a dispute about the time for completion a logical analysis includes the logic required for in the establishment of a CPN (critical path network)".* These cases suggest that the courts are more likely to accept analysis based on methodical calculation, not theoretical and vague impressions.

With regard to the issue of entitlement to an extension of time, the general principle is proving that the delay event, which according to the contract entitles the contractor to such entitlement has or will cause delay to completion date (Bramble and Callahan, 2000; Pickavance, 2005). The requirement for establishing this proof is often by showing that the event was on or will be on the critical path of the work. Paragraph 15 of the judgement in *Henry Boot v Malmaison* confirms this:

> "*The respondent was entitled to respond to the claim both by arguing that the variations, late information and so on relied on by the claimant did not cause any delay because they were not on the critical path and positively by arguing that the true cause of delay was other matters".*

This principle also received support in *Brompton v Hammond (No. 7) (2001) 76 Con L.R. 148* where it was alleged that the architect had been negligent in awarding extension of time. The judge stated the following at Paragraph 32 of his judgement:

> *"……..In order to make an assessment of whether a particular occurrence has affected the ultimate completion of the work, rather than just a particular operation it is desirable to consider what operations, at the time of event with one is concerned happens are critical to the forward progress of the work as a whole."………*

Also in *Balfour Beatty v The Mayor and Burgesses,* the judge expressed at paragraph 30 of the judgment interesting statements that suggest that delay claims analysis based on CPM are important requirements:

> *"………..From the material available to me it is clear that BB did little or nothing to present its case in a logical or methodical way. Despite the fact that the dispute concerned a multi-million pound refurbishment contract no attempt was made to provide any critical path. The work itself was no more complex than many other projects where a CPN is routinely established and maintained……………….*
>
> *A valid critical path (or paths) has to be established both initially and at every later material point since it (or they) will almost certainly change".*

Further confirmation of the requirement to establish critical path in delay claims is provided in the judgements of *Motherwell v Micafil Vakuumtechnik (2002) 81 Con L.R. 44 and Balfour Beatty construction Ltd v Serco ltd (2004) EWHC 3336 (TCC).* At paragraph 562 of the *Motherwell* case the judge observed:

> "*Crucial questions are (a) is the delay in the critical path and, if so, (b) is it caused by Motherwell? If the answer to the first question is 'Yes' and the second question is 'No' then I must assess how many additional working days should be included".*

Paragraph 44 of the judgement in *Balfour v Serco* noted:

> *"I note that it is common ground between the programming experts, Mr Kaletka and Mr Dedha that, in the event, the critical aspect of the works has turned out to be the installation of two signs, known as '19TO3' and '19TO4' at Penrith. These signs have yet to be installed. In these circumstances it seems to me that, for the purposes of assessing Balfour Beatty's entitlement to an extension of time, it is necessary to focus on these two signs and examine the effect of the requirement to comply with the NOD regime upon them. In these circumstances I ignore, for these purposes, the events summarised in claim 12 under the heading, 'Actual delays' and Balfour Beatty's other extension of time claims on the footing that those events were non-critical".*

Having established that the CPM analysis is preferred by the courts in delay claims preparations or assessment, the next important principle that needs to be looked at is how such analysis should be performed or which DAM is appropriate to use. In *John*

Baker v. London Portman, the impacted as-planned analysis, involving taking the original programme as the basis of the delay calculation and inserting delay defaults into it to determine when the work should have finished as a result of those delays, was accepted by the judge. In this case, there was very little as-built information available which made it appropriate to use this methodology (Pickavance, 1997).

The judgment in the recent case of *Mirant Asia-Pacific Construction (Hong Kong) Ltd v Ove Arup Partners International Ltd (2007) EWHC918 (TCC)*) contains interesting statement on the meaning and application of CPM-based analysis. This dispute relates to claims brought against *Arup* (defendants) by *Mirant* (claimants) for losses in connection with failings of boiler house foundations that were designed by Arup. One of the issues examined by the judge, HHJ Toulmin CMQ QC, was whether delay to one part of the construction programme was on the critical path and whether delays due to remedial works, which was carried out as a result of foundation settlement, had delayed completion. The decision of the judge which was upheld by the Appeal Court was that Arup had been negligent in its duty in contract and tort not to cause economic loss to its client but a careful evaluation of the facts and of the programming data concerning the project revealed that this negligence had not caused the damages being claimed and therefore all of Mirant's claims were dismissed. In making this decision, the judge made the following statements at paragraphs 119 to 137 of the judgement:

> *"………..What is known as the Critical Path Method is frequently used by the construction industry both in the United States, the United Kingdom and elsewhere in planning construction projects and in analysing the causes of delay……….*
>
> *As computers have become more sophisticated, the critical path analysis has been enabled to become more sophisticated. This has become an invaluable tool which enables a complex construction Project to be managed with better available information. The analysis will identify at a given date which important aspects of the Project are falling behind the programme, particularly if they are on or close to the*

critical path, what if any is the impact on other aspects of the programme and where additional resources need to be placed. It will also demonstrate where activities are ahead of what is planned and enable a decision to be taken on whether planned activities need to be rescheduled……….

Windows analysis is the most accepted method of critical path analysis. As Pickavance makes clear at page 572 of his book, "Windows" (and "Watersheds") are not methods of analysis in themselves: they are merely aspects of conducting the critical path analysis. In essence they represent the division of the overall construction period into smaller periods into which each new set of corresponding progress can be entered into the programme and analysed…….

The term "Windows analysis" refers to the regular reviews and updates undertaken by the contractor, normally monthly. These periods of time would be described as monthly windows. Unlike previous monthly reviews, the planner would use sophisticated software programmes to plot which activity or activities were on and which were near to the critical path each month. The programmes would take into account those activities which had started early or had been delayed. Also built into the programmes would be the progress of those activities which had started since the previous monthly window. This would enable the employer and the contractor to analyse over the relatively short periods of time what changes had occurred, and identify what problems needed to be investigated and put right………

The analysis would also identify delay, enabling those concerned to investigate and, if appropriate, agree the cause at an early stage. A monthly review would, in a complex Project like Sual, have enabled the consortium to see what activities were at or close to the critical path and to take urgent action where necessary. It would also have enabled a much more sophisticated retrospective analysis of the delay to be undertaken than that which was able to be carried out…………….”

This detail and lengthy comments suggest that the courts in UK are becoming more adept at dealing with CPM applications in DD claims resolutions, which has been the wish of most practitioners and researchers, judging from the *SCL Protocol* (SCL, 2002) and other surveys (e.g. Harris and Scott, 2001; Scott *et al*., 2004). Courts in the US have long gone past this stage as most of their judges are knowledgeable about CPM and are quite happy to work through, the details of complex network programme, for instance (Kallo, 1996; Wickwire and Groff, 2004).

Although the CPM has gained recognition as a very useful tool in proving claims, its major criticism has been on the tendency for some unscrupulous contractors and

employers to subject it to abuse by manipulating the analysis process to give results that the analysts wants. This is a major concern because modern computers have become more sophisticated and user-friendly; providing the opportunity to easily handle, sort, manipulate and present, in a short space of time, vast quantities of data and results of a complex delay analysis problem. The courts and other triers-of-facts have therefore been extra vigilant with CPM usage in delay claims and will not naively accept as accurate complicated and unintelligible analysis based on fancy computer-generated results (Schumacher, 1995: Wickwire and Groff, 2004).

The proper use of the CPM for conducting transparent and accurate analysis is therefore a matter of great importance that analysts have to note. More recent examples that illustrate the need for ensuring correct analysis can be found in *Skanska Construction UK Ltd v Egger (Barony) Ltd (2004) EWHC 1748 (TCC), Great Eastern Hotel Company Ltd v John Laing Construction Ltd (2005)EWHC 181 (TCC) and City Inn Ltd v Shepherd Construction Ltd (2007) CSOH CA101/00.* These cases also contain some helpful advice on the approach taken by the courts in relation to the use of experts in construction delay claims assessment.

Egger, a wood and other timber-based product firm entered into a contract with *Skanska* for the construction of a sophisticated wood chipping plant in Scotland. The project's guaranteed maximum price was £12m. The disputes concerned claims made by Skanska in the order of a further £12 million relating to what it argued were due to delays, extensions of time and loss and expense. There was also a counterclaim from Egger for more than £4 million. At trial, each party adduced expert evidence of programming experts, who used very different methods to analyse the evidence relating to delays. Even though the expert engaged by Skanska employed less

sophisticated computer software with little resources at his disposal compared to that of Egger, the Judge, HHJ Wilcox expressed preference for the approach adopted by the former describing him as "*objective, meticulous as to detail, and not hide bound by theory when demonstrable fact collided with computer program logic*". On the other hand, the judge considered the approach of Egger's witness to be highly flawed criticising it for errors made in reconstructing the initial contract programme in a computer-based CPM and therefore not reliable to use as a baseline for the analysis:

> "*Mr Pickavance produced a report of some hundreds of pages supported by 240 charts. It was a work of great industry incorporating the efforts of a team of assistants in his practice. It was evident that the report, ... was largely based upon factual matters digested for Mr Pickavance by his assistants .... There were times when the impression was created that Mr Pickavance was not entirely familiar with the details of the report, which he signed and presented. ... There were pressures of time upon him. This and the extent of reliance upon the untested judgment of others in selecting and characterising the data for input into the computer programme however impeccable the logic of that programme, adversely affects the authority of the opinion based upon such an exercise.*
>
> *... It is evident that the reliability of Mr Pickavance's sophisticated impact analysis is only as good as the data put in. The court cannot have confidence as to the completeness and quality of the input into this complex and rushed computer project. I preferred the evidence of Mr Simpson as to programming and planning matters to that of Mr Pickavance.*"

The case of *Great Eastern v Laing* concerned the refurbishment and extension of the Great Eastern Hotel in London. The works were carried out by trade contractors with Laing as construction manager of the project. The dispute involved claims raised by Great Eastern in respect of project delay of about 44 calendar weeks. By way of defence, Laing made a counterclaim based upon alleged material misrepresentation and also denied culpability of the delay by pointing finger at both other parties and other concurrent causes of delay. In relation to the case on delay, the expert witnesses of the parties approached their analyses of the delay using two different approaches which attracted insightful comments from the Judge. His did not find favour with the approach adopted by the defendant's expert witness:

> *“I reject Mr Celetka's evidence that the late design information either caused or contributed to the critical delay in the Project. His analysis was self confessedly incomplete. He did not have the time to approach the research of this aspect of the case in the complete and systematic way, furthermore, the impacted as planned analysis delay takes no account of the actual events which occurred on the Project and gives rise to an hypothetical answer when the timing of design release is compared against the original construction programme. Thus it would take no account of the fact that the design team would have been aware of significant construction delays to the original master programme, and would have been able to prioritise design and construction to fit this. Furthermore, Mr Celetka in his report compares the timing of the actual design releases against an original programme which was superseded by later versions of the procurement programme on which Laing showed later dates for the provision of the information required”.*

The judge was rather satisfied with the analysis of the claimant’s expert witness:

> *“I accept Mr France's careful evidence as to the impact of the flow of design information throughout the Project. It was based on thorough research and objective analysis. Whilst there was some delay in relation to the provision of design information, it was not critical delay. It was the delay endemic in a large and complex Project when it is anticipated that the design would evolve and some information was provided "just in time….."*
>
> *“Mr France took account of the actual events in his researches and exhibited in his researches and conclusions the clear-sighted objectivity that informs the whole of his report…”*

The case of *City Inn v Shepherd Construction Ltd* (*2007) CSOH 190* concerned the construction of a hotel in Bristol under an amended JCT 80 Form. Matters in dispute included the pursuer, *City Inn,* seeking a declarator that the defendant, *Shepherd Construction Ltd* were not entitled to the contended 11 weeks time extension and even the four-week extension granted by the architect. Both parties relied upon the expert evidence of their programming experts, who were described by the judge, Lord Drummond Young as *“well qualified to speak about the issues that arose in the case”*.

The defendant’s expert did not carry out a critical path analysis, giving the reason that he did not have access to an electronic version of the defenders' original programme

for the project. His approach, which was a form of As-planned v As-built method, was therefore criticised by the pursuer for not based on the critical path analysis. Although the pursuer's expert carried out critical path analysis of the as-built programme, it was rejected by the judge as indicated in paragraph 29 of the judgement:

> "*In my opinion the pursuers clearly went too far in suggesting that an expert could only give a meaningful opinion on the basis of an as-built critical path analysis. For reasons discussed below (at paragraphs [36]-[37]) I am of opinion that such an approach has serious dangers of its own. I further conclude, as explained in those paragraphs, that Mr Lowe's own use of an as-built critical path analysis is flawed in a significant number of important respects. On that basis, I conclude that that approach to the issues in the present case is not helpful. The major difficulty, it seems to me, is that in the type of programme used to carry out a critical path analysis any significant error in the information that is fed into the programme is liable to invalidate the entire analysis. Moreover, for reasons explained by Mr Whitaker (paragraphs [36]-[37] below), I conclude that it is easy to make such errors. That seems to me to invalidate the use of an as-built critical path analysis to discover after the event where the critical path lay, at least in a case where full electronic records are not available from the contractor."*

In concluding, the judge expressed his preference to analysis based on factual evidence, sound practical experience and common sense despite that such analysis might not be based on critical path analysis and jettisoned the approach based on flawed as-built critical path analysis.

The foregoing comments suggests that if critical path analysis is to be relied upon in delay claims analysis, then it has to be done accurately, and with due recognition of practicality and pragmatism. There is also the need for analysts to take into account actual events which occurred on the project otherwise the analysis would only produce hypothetical answers. This latter requirement received support in the recent case of *Leighton Contractors (Asia) Limited v Stelux Holding Ltd HCCT 29/2004* in the Court of First Instance of Hong Kong. Disputes between the parties, which were referred to arbitration, include claims arising from critical delays allegedly due to the defendant releasing tender information for the heating, air conditioning and electrical

subcontract works late. In arguing its case, Leighton contended that the contract made it clear that both “delay” and “likely delay” gave proper grounds for an extension of time and therefore if the arbitrator thought that an event was likely to cause delay by standing in the architect’s shoes at the time of the delay events, then an extension of time should have granted. The arbitrator rejected these contentions concluding that the late information could not have caused actual delay. This decision was upheld by the court.

The above cases suggest that although CPM techniques are recognised as appropriate for delay analysis, it is very important for contractors and employers or their agents to employ techniques that consider what actually happened on site based on factual evidence. Theoretical delays calculated without taking into account actual project records are unlikely to succeed. However, the cases do not seem to make things clear as to which methodology is the most acceptable to the courts.

3.7 Summary

This chapter reviewed the theoretical and legal principles that underlie the preparation or assessment of projects DD claims. The review was based on general research papers on DD analysis and UK cases and was limited to relevant issues such as: the resolution of concurrent delays, float ownership, resolving delays when programme shows early completion, delays experienced after completion date and the requirements for the production or assessment of DD claims. The findings of this review offered important information on the requirements of properly performing DD analysis, which served as the basis for some of the issues that were empirically

investigated and the best practice recommendations proposed. A summary of the main findings are as follows:

(a) There is no common definition amongst practitioners as to what concurrent delay means. Despite this, there seem to be some accepted principles with regard to its effect on the entitlement to extension of time and compensation to prolongation cost. These principles, similar to the approach adopted in the US, are:

- the contractor is entitled to extension of time but no compensation in the situation where the contractor delay is concurrent with an employer delay
- to be entitled to compensation as well, the contractor should be able to separately identify the additional costs caused by the employer delay from those caused by the contractor delay.

The analysis of DD claims therefore requires the use of methodologies that can take account of concurrent delays and their effects.

(b) Float is a resource which can be increased or depleted due to the actions of the employer or the contractor. Whether a contractor will be entitled to a time extension or otherwise is significantly affected by the issue of who owns float. However, this issue remains unresolved (probably because it is not addressed in most contracts) and a potential source of dispute.

(c) Contractors are entitled to complete on an earlier date than the specified contractual completion date but the employer is not obliged to provide information or other deliverables to ensure the former, without deliberately hindering the contractor.

(d) Time extensions awards for delay claims involving employ-caused delays occurring after the expiry of contractual completion date when the contractor is

in culpable delay, are likely to be resolved by adding the amount of time taken by the delay to the date upon which the contractor should have finished the work, be it the original or adjusted completion date, even though this may be well before the date upon which the delay-events events occurred.

(e) The CPM is now an essential tool for the resolution of DD claims as it makes it possible to satisfy, among others, the requirements of proving or disproving extension of time entitlements by establishing whether or not the delayed activities were on the critical path and the effect of such delays on this path.

(f) The use of CPM approach for delay claims productions or assessment should be backed by the following principles:

- the approach should be backed by good factual evidence;
- effective presentation of that evidence through clear and transparent analysis;
- those giving evidence in Court in the capacity of an expert, must ensure that their approach is both balanced and objective; and
- the expert should also be thorough, clear and sensible in his/her approach.

(g) Even though UK courts are increasing becoming aware of the use of DAMs, than hitherto was the case, the question of what constitutes the proper applications of these methods and which is the most appropriate are unclear from the review of the cases. The literature review and empirical investigations on existing DAMs (reported in Chapters 5 and 6) were therefore devoted to resolving some of these questions.

CHAPTER FOUR

4 PLANNING AND PROGRAMMING ISSUES

4.1 Introduction

It can be inferred from the previous chapter that a vital part of the procedure in the resolution of DD claims is for claimants to produce adequate documentation to show that the opposing party is responsible for the additional time and/or cost being claimed. Often at the centre of this is the question of availability and accuracy of information on two matters: (i) exactly what the contractor would have done had the event or circumstance complained of not occurred and (ii) what the contractor actually did. Sources of information for answering these questions include the contract documents, baseline programme, progress reports, project, correspondence, site dairies, minutes of meetings, supervision and inspection reports, resource usage and costs and (Thomas, 2001; Pickavance, 2005). A major source of the information is also generated by contractors on a periodic basis in the form of statused/updated and revised programmes. Timely keeping of these information in an accurate, well-organised manner throughout the life cycle of the project is a key task in preparing, analysing and resolving DD claims (Kartam, 1999). However, a common thread running through literature in textbooks and research papers is that there is usually a dearth of relevant, useful and contemporaneous documentation (Worby *et al*, 1985; Pickavance, 2005).

Notwithstanding this, much of the research effort that has gone into finding solutions to the problems in DD analysis has been limited to developing of methodologies for analysing DD as highlighted in Section 1.1. It is noteworthy that these methodologies are of very little use in practice if the information required for their proper use is

usually lacking. Investigating issues of construction planning and programming, which is a major source of the information, is therefore an important consideration in the development of an appropriate framework for improving DD analysis. To gain an appreciation of the need and areas for such an investigation, this chapter first reviews how deficiencies in contractors' programmes and programming practice may be contributing to the problem of lack of information. It then identified the possible causes of these deficiencies and areas that require further studies for promoting improved practices that will enhance proper DD analysis.

4.2 Deficiencies in Contractors' Programmes

Most construction contracts require the contractor to provide a programme at the commencement of the works to show the sequence and timing of the construction activities. Not only do programmes serve as tools for managing projects, they are also valuable sources of information for identifying and modelling delays and their effect on progress. The use of computerised CPM for this latter function is now the norm (Wickwire *et al*, 1989; Kallo, 1996; Pickavance, 2005). This reliance is due to the fact that the programmes indicate the intent and also offer useful historical records, which enable the determination of the effects of delay events and calculation of damages. For the programme to be appropriate for this function, it has to be free of any form of deficiencies (Reams, 1990; Bramble and Callahan, 2000). However, a number of commentators have observed that most contractors' programmes have deficiencies thereby making the resolution of DD disputes more difficult. In his doctoral research into contractors' programmes on UK construction projects, Scott (1991) found that most contractors' programmes are poorly produced and lack appropriate activity details. Keane (1994) also noted from his doctoral work that the preparation, format

and logical basis of most contractors' programmes are usually unsatisfactory. In addition, contractors are reluctant to provide details of envisaged resources in their programmes thus making it difficult to assess the impact of delays on usage of resources and their productivities in the event of delays (Yogeswaran *et al*, 1998). Winter and Johnson (2000) also shared the view that most contractors' programmes do not have the necessary links, are not resource-driven and, on the whole, are not prepared to reflect what will actually happen on site, but are designed to win the job for the contractor.

The foregoing supports the view that a considerable proportion of contractors only pays lip service to programming and only employs CPM for mere superficial compliance with specifications (Revay, 2000; Bramble and Callahan, 2000). Whist there are obvious benefits to proper programming, it is surprising that many contractors do not provide employers with a proper programme and then manage it appropriately. Some researchers and commentators have identified a number of reasons for this poor practice. In his research work, Jaafari (1984) observed that CPM scheduling was not performing well because of: lack of experience and willingness on the part of contractors, difficulty in controlling performance against the plan due to general variations, the use of multiple contracts and lack of detailed design before project commences. Similar findings were identified by Nahapiet and Nahapiet (1985) in their research into management of construction projects in the UK and US. They observed marked reluctance by contractors to update programmes even when the nature and number of activities had altered over time. The reasons given for this reluctance ranged from the amount of work reprogramming would entail, to the almost certain knowledge that as soon as any revision had been submitted, further changes would invalidate it. In addition, Mace (1990) in a review of programming

practice identified a number of problems: treating programmes as a recording mechanism instead of as a forward planning; lack of adequate information on various procurement times of some activities; and the tendency of relying entirely on computer with little consideration of the users of the plans on error checking.

The implication of the above state of affairs is that most constructors' programmes are likely to suffer from a number of deficiencies. Typical of the deficiencies that will impair their utilisation for DD analysis include: poor baseline programmes, failure to update programmes, and inadequately updated programmes. These deficiencies can lead to difficulties and disputes in resolving claims because, in the absence of properly prepared and timeously updated CPM programme, it would be difficult to determine whether delayed completion is indeed due to the specific types of delays complained of, i.e., causal connection between breach and damage is not readily apparent (see Section 3.6).

4.2.1 Poor baseline programmes

The baseline programme submitted by the contractor is the initial as-planned programme that reflects the intended plan for executing the project. Its importance in DD analysis lies in its ability to demonstrate the period of time within which the contractor would have completed the project absent any delays. Shortcomings in baseline programmes that often make them invalid or unreliable tools for this purpose include the following.

(i) Programmes prepared in a format other than CPM: Except in simple delay claims, CPM format is the highly recognised tool for proving delay because it allows the determination of the critical path and shows the interrelationships among multiple causes of delay (Wickwire *et al*, 1989; Kallo, 1996).

(ii) Incomplete programmes: That is failing to include all the work that must be undertaken. This makes it difficult to evaluate how all activities and their delays interact to affect project completion (Bramble and Callahan, 2000; Zafar and Rasmussen, 2001).

(iii) Insufficient details provided for the programme activities: This makes it difficult to measure progress and the effect of delays adequately. For instance, consider an employer ordering a variation in a building project that affected an activity on the critical path described as "construct first floor slab". If this variation actually affected the scope of some of the specific work tasks within this activity, then the actual delay incurred as a result of the variation cannot be accurately determined.

(iv) Unreasonable logic or relationships between activities: Such relationships do not accurately represent the contractor's intended sequence of work (Reams, 1990; Zafar and Rasmussen, 2001), and thus would result in erroneous delay analysis results.

(v) Insufficient provisions for constraints likely to be encountered: Examples of such constraints include local weather conditions; statutory requirements and restrictions, contractual stipulations on the order in which the works are to be completed; time required for employer or other agency for approvals, inspections and information and availability of equipment and material (Reams, 1990; Zafar and Rasmussen, 2001).

(vi) Unrealistic planned resource allocations. This results in incorrect duration and cost allocation of activities making the baseline programme unreliable (Kartam, 1999; Zafar and Rasmussen, 2001).

(vii) Unrealistic durations of major activities: The effect of this is the creation of unreasonable floats and incorrect project completion date in the baseline programme.

Thus, for the baseline programme to be a credible tool in DD analysis it has to be free of the above pitfalls. In the case of *Pacific Construction Co. Ltd. v Greater Vancouver Regional Hospital District* (1986) 23 CLR 35 (B.C.S.Ct), the British Columbian Supreme Court emphasised the necessity of evaluating the validity and reasonableness of contractor's baseline schedule before employing it in delay analysis. Similarly, in *Balfour Beatty v London Borough of Lambeth (2002) 1 BLR 288*, the His Honour Judge Lloyd QC observed: " *By now one would have thought that it was well understood that, on a contract of this kind, in order to attack, on the facts, a clause 24 certificate for non-completion (or an extension of time determined under clause 25), the foundation must be the original programme (if capable of justification and substantiation to show its validity and reliability as a contractual starting point) and its* ……"

4.2.2 Failure to update programmes

Programme updating is reviewing periodically the plan and progress of work. This is necessitated by the fact that the uncertain conditions in which construction projects operate inevitably cause plans and estimates to change (Laufer *et al.,* 1994). There may also be a need to evaluate work procedures, performances, delays and their associated causes (Kursave, 2003).

As a result of the inevitable changes in construction projects, failure to update the programme would result in lack of important information such as:

changes in critical path;

actual start and finish dates and percent complete for each activity;

milestone status and potential problem areas;

logic changes from previous updates.

These types of information serve to establish when and what changes occurred during the course of the project and enable DD analysis in "real time" (i.e. determining the effect of individual delays on project as at their time of occurring). Thus failure to update the programme regularly can create difficulties in DD claims resolutions. For instance, in the US cases of *Fortec Construction v. United States (1985) 8 Cl. Ct. 490* and *Continental Consolidation Corp. v. United State. Nos. 2743 and 2766, 67-2 BCA 6624*, the CPM schedules used to evaluate delays were rejected by the courts because they were not updated to reflect changes as they occurred.

4.2.3 Inadequately updated programmes

An updated programme that does not adequately reflect the contractor's as-built progress as the project unfolds would not be able to accurately predict project delays and their impacts. Thus, to maintain the updated programme as a realistic tool for assessing delays, it has to be a competent one. There are different approaches to updating which can affect the adequacy of updated programmes.

One approach is updating the programme as and when the scheduler deems it necessary. For instance, updating the programme when the project falls behind schedule or when unexpected changes in the programme occur as required by some contract documents. Other important factors influencing the frequency of updating include occurrence of specific control events, the degree of uncertainty, the magnitude of the project, the time of completion and the troubles encountered (Kursave, 2003).

Another approach involves pre-determined periodic updates. This approach has the tendency of giving more accurate picture of how the work progressed than in the first approach. This is because in this first approach for instance, the scheduler may not be fully aware of project slippage so that, by the time he/she agrees that an update is needed, the project might have slipped considerably and contemporaneous information for updating might not be readily available.

Other factors affecting the adequacy of updated programmes are the degree of detail of the updating. As a minimum in each updating process, the following have to be identified: actual start dates, actual finish dates, percent complete and remaining durations per schedule activity (Kursave, 2003). The accuracy and timing of these data are also very important in the production of proper updated programmes.

4.3 Causes of the deficiencies

The production of a reliable baseline programme involves the collation of information from various sources. *A guide to good programming practice*, produced by the UK's Chartered Institute of Building (CIOB, 1991) has grouped these sources of information into a number of forms:

project information (contract, design, site, specialist);

production information (staff experience, previous jobs records, etc);

reference information (industry data, papers, periodicals);

factual information (weather records, dimensions of equipment, etc) and

the planning brief.

Specific skills are required in order to gather this information and translate it analytically into a reasonable baseline programme and other planning outputs such as method statements, cost and cash flow forecasts, manpower requirements, material requirements, project organisation and site set up and layout.

A number of issues tend to impact on the planning and programming process, which can cause deficiencies in the programme produced and their subsequent updates. A review of research-based papers and published commentaries by practitioners identified the following as the possible causes of deficiencies in programme and programming practice.

- inadequate planning expertise;
- poor enforcement of planning obligations;
- poor personal liaison of planners with others;
- lack of proper communication;
- inadequate planning effort;
- inefficient allocation of construction planning resources;
- inadequate contractual provisions for programming;
- poor involvement of field personnel;
- insufficient time and information for tender preparation;
- contract administrator's programming expertise; and
- programmesmanship.

4.3.1 Inadequate planning expertise

The achievement of satisfactory programme demands planners of high competence and experience (CIOB, 1991). However, in research reported by Kelsey *et al.* (2001)

some planners felt that two generation of planners (taking a generation at 15 years) had now appeared who had little site experience. Furthermore, Street (2000) in a review of pitfalls of CPM scheduling on construction projects, noted that most contractors do not have in-house CPM expertise. This situation is likely to result in poorly developed and poorly maintained schedules.

4.3.2 Poor enforcement of programming obligations

It appears from the previous section that most contractors view programmes as nothing more than a requirement of the contract and do not take it seriously enough to properly develop and maintain them. Moreover, a clause in contract documents does not of itself encourage the use of CPM-based programme, rather top management support is vital for their continual usage (Esthete and Langford, 1987). Poor enforcement of planning obligations will thus offer too much flexibility within the programming requirements resulting in lack of strict adherence to scheduling specifications that are meant to ensure proper scheduling of the work.

4.3.3 Poor personal liaison of planners with others

The review identified two main issues responsible for this cause. Firstly, planners are often isolated from formal administration channels due to the nature of their work and this creates difficulties for them in gathering of information (Cullen and Nankervis, 1985; Laufer, *et al*., 1994). Secondly, planners are not always completely open on their programmes, particularly with the employer, probably for fear that their own programmes could be used to defeat any of their claims (Revay, 2000). Conversely, this lack of openness makes the employer very cautious about being tied to a

contractor's programme. Apprehension of this sort is likely to affect proper preparation and maintenance of programmes.

4.3.4 Lack of proper communication

Timely, reliable and clear information gathering and distribution is a central issue in planning during construction (Laufer, *et al*., 1994). Thus improper communication between project stakeholders particularly site managers, subcontractors and architect/engineer team will affect the availability of information for effective programme management. For instance, the practice of issuing verbal instructions and hand drawn sketches by the designer's site representative without a confirmation by the contractor (as some contract forms require), often result in difficulty in finding project records when investigating causes of delay some time later. Another example is the situation where the architect or engineer issues drawing under cover of instructions, letters, transmittal sheets and other forms, without distinguishing between explanatory details and changes to the original design. This practice may not facilitate possible review of effects on programme and thus contributes to failure by the contractor to give notice of delay, or extra cost at the earliest possible time.

4.3.5 Inadequate planning effort

A study by Faniran *et al.* (1994) shows that the extent to which emphasis is placed on the determination of construction methods during planning has a significant effect on the improvement of construction planning effectiveness. However one major deficiency in construction planning practices is over-emphasis on scheduling and control at the expense of methods as highlighted in a paper by Laufer and Tucker (1987). In addition, relatively little effort is made by planners to seek required

additional information during planning with the usual practice being to feed deterministic planning models with pure guesswork data (Arditi, 1981; Laufer and Tucker, 1987).

4.3.6 Inefficient allocation of construction planning resources

Construction planning effectiveness can be improved by increasing the amount of resources invested in construction planning (Faniran *et al.*, 1994; 1998). However, there is evidence also that investing in construction planning beyond an optimum point will lead to deterioration of project performance (Faniran *et al.*, 1999; Neale and Neale, 1989). Therefore inefficient allocation of resources for construction planning has the potential of negatively affecting project performance.

4.3.7 Poor involvement of field personnel

Effective programming requires the involvement of many parties (Laufer, *et al.*, 1994). More importantly, field supervisors must be totally familiar with and in agreement with all details of the programme. As Baki (1999) puts it, the more input the person responsible for carrying out the plan has in the development of the plan, the more likely it is to be followed. However, earlier research in UK (Cullen and Nankervis, 1985) indicated that field personnel are often excluded from strategic planning and from receiving planning information. This exclusion would work detrimentally against scheduling process thereby resulting in deficiencies in programmes that could have been avoided had the field personnel been consulted.

4.3.8 Insufficient time and information for proper tender preparation

Adequate planning time prior to commencement of work on site is one of the factors significantly responsible for effective planning (Faniran *et al.*, 1994). However, research by Kelsey *et al.* (2001) shows that most planners work under shorter time constraints during tender preparation which may affect the quality of pre-contract programmes submitted with the contractors' tenders. The planners interviewed in that research also complained of consistently poor quality and insufficient information for tender programme preparation leading to guessing for missing information. This affects the use of the tender programmes as proper bases for construction programmes or sometimes for assessing extensions of time when it is the only programme available prior to experiencing delays.

4.3.9 Inadequate contractual provisions for programming

Most of the UK contract documents do not have adequate provisions and sufficient emphasis for effective preparation and maintenance of contractors' construction programmes (Thomas, 2001; Pickavance, 2005). Scheduling specifications that lack important programming requirements offer an advantage to unscrupulous contractor. In contrast, the situation in the US may be better because as late as over three decades ago, most conditions of contract required a schedule in CPM or PERT format with a requirement to update periodically the schedule to reflect contract performance (Wickwire *et al*., 1989).

4.3.10 Contract administrator's programming expertise

For prompt and proper assessment of extensions of time claims, most forms of contract require the contractor to provide timely notice of delay and its particulars to

the contract administrator. However, it is not uncommon for contractors to provide brief information (if at all) on particulars of delay events making it difficult for the contract administrator to assess properly the effects of delay (Thomas, 2001). Presumably the contract administrator might be expected to identify all relevant particulars required to make a decision on the extension of time and ask the contractor to supply them. Some contract forms (e.g. clause 25.3.4 of Joint Contracts Tribunal Standard Form of Building Contracts, 1998 Edition) require the contract administrator to consider the reasonableness of the contractor's endeavour to prevent or minimise delay and the effect of all other events even if not notified by the contractor when reviewing extension of time claims. As a result of these responsibilities, contract administrators with inadequate expertise on programming would not facilitate proper maintenance of programme for effective delay assessment.

4.3.11 Programmesmanship

This is a ploy used by contractors by deliberately submitting over-optimistic programmes in the hope of sustaining a delay claim even if the contract is completed within the contract period. Typical examples include a contractor's programme having unrealistic early completion date, artificial logic to exaggerate known delay, artificial activity durations and logic to hide float (Zack, 1993).

4.4 Programming practice contribution to DD analysis difficulties

As a summary of the review, Figure 4.1 illustrates how poor programming practice contributes to difficulties in DD analysis. This shows that remedying the deficiencies in contract programmes is an important requirement for the achievement of improved

DD analysis. To devise a framework for ensuring this, areas that require further attention include:

- employer and planners involvement in programming after contract award;
- programme management
- the importance/use of programmes in DD claims
- progress reporting and its content
- output of the planning process and nature of the programmes produced;
- the extent of use of programming software packages.

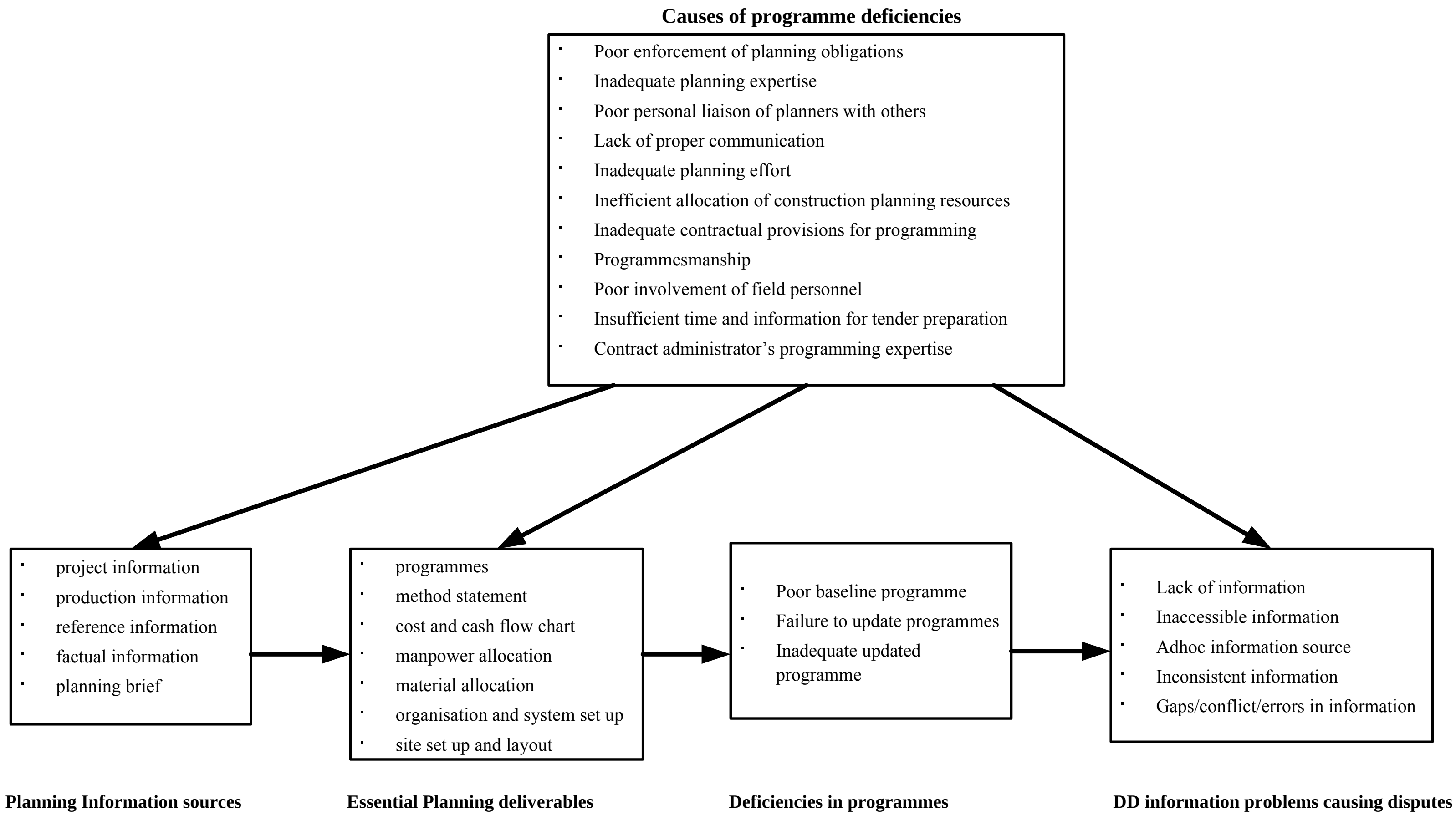

Figure 4.1 The relationship between programming and DD information problems/disputes

4.5 Summary

This chapter has sought to establish the deficiencies in contractors' programmes that make them unreliable for DD analysis. The main deficiencies are poor baseline programmes, failure to update programmes, and inadequately updated programmes. Possible causes of these deficiencies identified include poor enforcement of planning obligations, inadequate planning expertise, poor inter-personal interaction of planners with others, lack of proper communication, inadequate planning effort, inefficient allocation of construction planning resources, inadequate contractual provisions for programming, programmesmanship, poor involvement of field personnel, insufficient time and information for tender preparation, and lack of contract administrator's programming expertise. To remedy these deficiencies and ensure better planning and programming practice for improved DD analysis, areas of further attention include:

employer and planners involvement in scheduling after contract award;

programme management

the importance/use of programmes in DD claims

progress reporting and its content

output of the planning process and nature of the programmes produced;

the extent of use of scheduling software packages.

These in addition to the results of questionnaire survey on DD methodologies (reported in Chapter 6) formed the basis of the interviews conducted following the survey. The interview was intended to establish the actual extent of the current programming problems affecting DD analysis so that appropriate recommendations for improvement can be formulated.

CHAPTER FIVE

5 METHODOLOGIES FOR ANALYSING DD CLAIMS

5.1 Introduction

The previous chapter reviewed important theoretical and legal principles that underlie the resolution of DD claims. The review established that DAMs based on CPM are recognised and accepted as useful in proving or disproving of DD claims. It also revealed that, whilst courts in the UK are becoming more adept in the use of these methodologies, it is unclear as to which of the available methodologies is most acceptable by the courts and how each should be applied appropriately. To enable further investigation of these matters, this chapter reports on a review of the existing DDA methodologies in respect of what these methods are, their applications, strengths and weaknesses.

As pointed out earlier in Section 3.1, there are two distinct groups of methodologies for undertaking DD analysis – the DAMs and DSAMs. The review therefore covered these methodologies under separate headings. To appreciate their differences and what each group entails, it first examines the distinction between delay claims and that of disruption.

5.2 Delay and Disruption contrasted

In the context of construction claims, the term "Delay", in its most basic form entails an increase in the time necessary to complete the project beyond that which was contemplated at the time the contract was signed. Damages under such claims usually involve claims for extended home and field office overhead, additional costs of

financing, and other time-related claim items (Haese and Dragelin, 2001). On the other hand, the term "disruption" is used to describe any material alteration in the performance conditions that were expected at the time of bid from those actually encountered, resulting in increased difficulty and cost of performance (Finke, 1997). Typical changes in working conditions include out-of-sequence work, trade stacking, unbalanced crews, excessive labour fluctuations, overtime, and working in adverse weather conditions (Hanna and Heale, 1994; Schwartzkopf, 1995). A classic result of disruption is loss in productivity as more labour and equipment hours will be required to do the same work in the end than would otherwise have been the case. The types of damages that are recoverable under delay claims and that of disruption are therefore different. Another significant difference between the two heads of claims is that unlike delay damages, disruption damages can occur regardless of whether project completion date changes or not. Delay in completion only occurs when the delays and/or disruption events lie on the project's critical path. It is for this close association between DD that the two groups of methodologies are often combined to produce a complete proof demonstration.

The DAMs make use of scheduling techniques such as CPM. Their application processes are largely analytical in nature, involving impacting a form of the construction schedule with facts surrounding the claims, to establish the amount of project delay caused by each of the parties involved. On the other hand, DSAMs involve the collection of facts, particularly on productivity, and interpreting them to demonstrate cause-and-effect relationships between the alleged disruption events and the extra time and/or costs suffered as a result. Boyle (2007) describes this process as deductive and that of delay analysis as inductive on the basis that the former often

begins with moving from the general to the specific and vice versa for the latter. Boyle (2007) colourfully illustrated this and other distinguishing features of the two processes as bookends supporting the claims (see Figure 5.1).

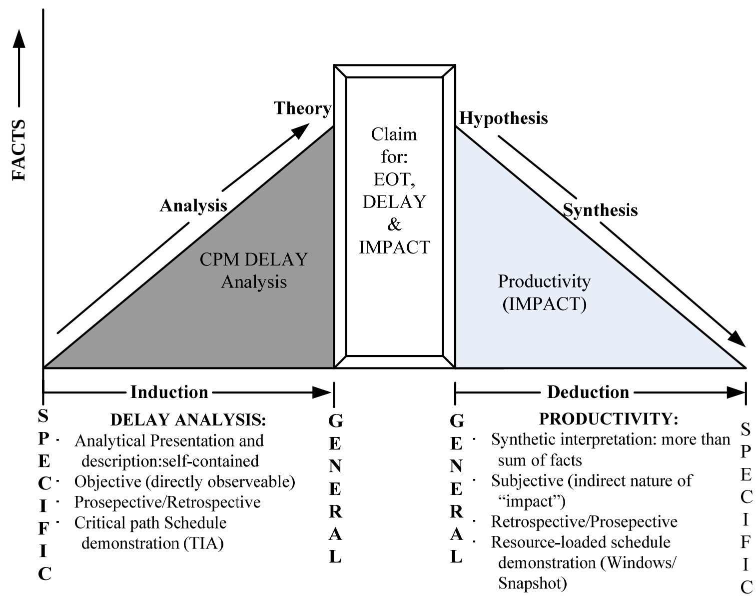

Figure 5.1 Delay and Disruption Analysis Depicted as Bookends Supporting a Claims (Boyle, 2007)

5.3 Delay Analysis Methodologies (DAMs)

Various DAMs, known by different terminologies among practitioners, have been reported in the literature (see Table 5.1). The common aim of these methodologies has been to investigate how delays experienced by the various project activities affect others and the project completion date and then to determined how much of the overall project delay is attributable to each party. However, the various methodologies achieve this at different levels of accuracies due to their different attributes. The following gives an overview of the difference between the various methodologies and their brief descriptions.

Table 5.1 Names of existing DAMs

	Common name	Literature review	Alternative names used by different authors
Non-CPM based techniques	**S-Curve**	Rubin *et al.* (1999)	**Dollar-to-Time Relationship** (Trauner, 1990)
	Global Impact technique	Leary and Bramble (1988); Alkass *et al.*, (1995; 1996); Pinnell, (1998)	
	Net Impact	Leary and Bramble (1988); Alkass *et al.* (1995, 1996)	**Bar chart analysis** (Zack, 2001; Lucas, 2002) **As-built bar chart** (Bordoli and Baldwin, 1998)
CPM based techniques	**As-planned vs. As-built**	Stumpf (2000); Lucas (2002); Lovejoy (2004); Pickavance (2005)	**Adjusted as-built CPM** (Leary and Bramble, 1988; Alkass *et al.*, 1996) **Total time** (Zack, 2001; Wickwire and Groff, 2004) **Impacted as-built CPM** (Pinnell, 1998)
	As-Planned but for	Alkass *et al.* (1996); Pinnell, (1998)	
	Impacted As-planned	Trauner, (1990); Pinnell (1998); Lucas (2002); Lovejoy (2004) Pickavance (2005)	**What if** (Schumacher, 1995) **Baseline adding impacts** (Bordoli and Baldwin, 1998) **As-planned-plus delay analysis** (Zack, 2001; Chehayeb *et al*, 1995) **As-planned CPM** (Pinnell, 1998)
	Collapsed As-built	Pinnell (1998); Stumpf (2000); Wickwire and Groff (2004); Lovejoy (2004)	**But-for** (Schumacher, 1995; Zack, 2001; Lucas, 2002) **As-built but-for** (Pickavance, 2005) **As-built subtracting impacts** (Bordoli and Baldwin, 1998) **As-built-minus analysis** (Chehayeb *et al*, 1995)
	Window Analysis	Galloway and Nielsen (1990); Bordoli and Baldwin (1998); Finke (1999); Lovejoy (2004); Pickavance (2005)	**Contemporaneous Period Analysis** (Schumacher, 1995; Lucas, 2002) **Snapshot** (Alkass *et al*., 1995; 1996) **Periodic update analysis** (Chehayeb et al., 1995) **Watershed** (Pickavance, 2005)
	Time Impact Analysis	Leary and Bramble (1988); Alkass *et al*. (1996); Pickavance (2005).	**End of every delay analysis** (Chehayeb *et al*, 1995) **Chronological and cumulative approach** (Wickwire and Groff, 2004)

5.3.1 Differences between the methodologies

The methodologies differ from each other based on the type of schedule techniques they require, the baseline schedule used and the mode of application. Based on these criteria, the various DAMs can be classified as shown in Figure 5.2.

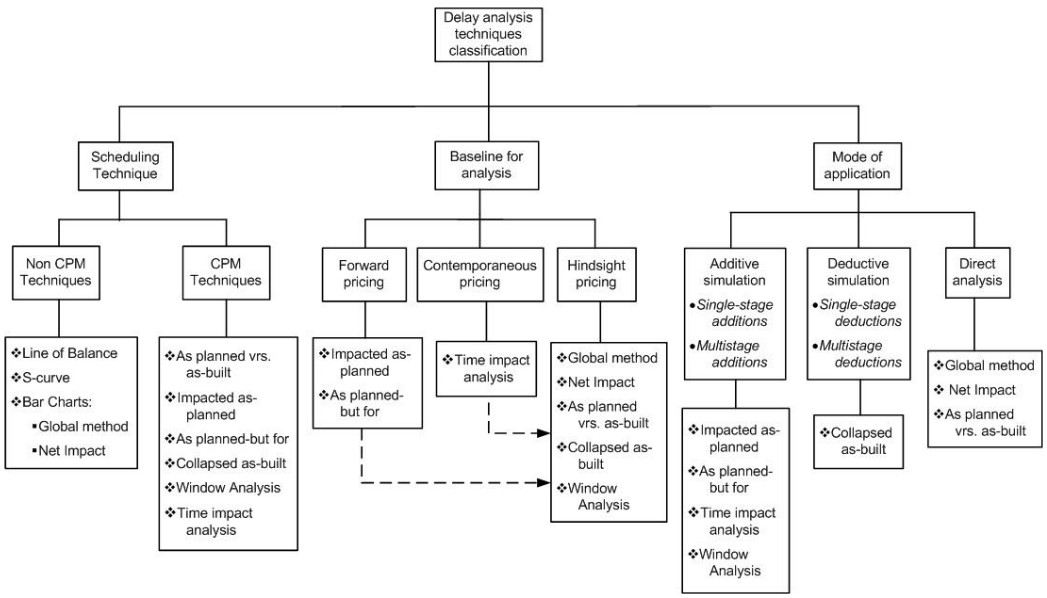

Figure 5.2 DAMs classification

On the type of schedule technique used, the methodologies can be grouped as CPM-based techniques and non CPM-based techniques. The former are more popular and highly recognised because of the numerous advantages of CPM in DA (see Section 4.2.1). On the other hand the non-CPM based techniques, particularly bar charts, are of limited help in proving the impact of delays because of their inability to show the true effects of delays on project completion (Wickwire and Groff, 2004). However, they can be successfully used to analyse some types of delay claims particularly those involving fewer activities and simple relationships (Pickavance, 2005).

According to Wickwire *et al*. (1989), the baseline or reference point used in delay analysis varies for the various methodologies depending on the choice between the following three options:

(i) *Forward pricing* – valuing the delay at its inception by impacting the contractor's baseline programme with the delaying events. Methodologies relying on such analysis include the impacted as-planned and the as-planned but for methods;

(ii) *Contemporaneous pricing* – valuing the delay as it is occurring or immediately after it has occurred. Methodologies for performing this include the Contemporaneous Period Analysis and the Time impact analysis.

(iii) *Hindsight pricing* – determining and valuing the delay after the project is completed. This is performed using methodologies such as Collapsed as-built, As-planned vr as-built and the Window analysis.

These options are highly influenced by the timing of the analysis. However, in practice methodologies suitable for performing forward and contemporaneous pricing (i.e. prospective analysis) can also be used for hindsight pricing (retrospective analysis). In this case the analysts would have the full benefit of hindsight as the analysis will be carried out after the fact.

The mode of application of the methodologies varies on three different modes: direct analysis, subtractive simulation and additive simulation.

<u>Direct analysis</u>

This involves the analyst examining the schedules as it is without carrying out any major adjustments or evaluations on the schedule. The methodologies using this type

of analysis are therefore relatively easy, simple and less expensive to implement. Examples include As-planned vrs as-built, Net impact and Global impact.

Subtractive simulation

This mode entails removing the delays of each party from the as-built programme to establish their effects on the completion date of the project. There are two main ways by which the delays can be removed (Trauner, 1990): removing all the delays in one go from a single as-built schedule (i.e. single stage simulation) or removing the delays in stages from multiple schedules (multistage simulation). The collapsed as-built method is an example of this type of simulation.

Additive simulation

Under this mode, the analysts formulate the delays as activities and add them to a schedule (the baseline programme or its updates) to establish their effects on the project completion date. As in the subtractive method, the additions can also be done in a single stage or multi-stages. Methods falling under this type of analysis are the impacted as-planned, as-planned but for, window analysis and time impact analysis.

Based on these different modes of operations, the level of analysis detail required varies for the various methodologies. Methodologies that make use of direct analysis are therefore often termed "simplistic methods" while those involving extensive modifications of the schedules as in additive and subtractive simulations are termed "sophisticated methods" (Alkass *et al.*, 1996). The latter groups tend to give more accurate results than the former but they require more expense, time, skills, resources and project records to operate (Lovejoy, 2004). These characteristics of the methodologies are illustrated in Figure 5.3.

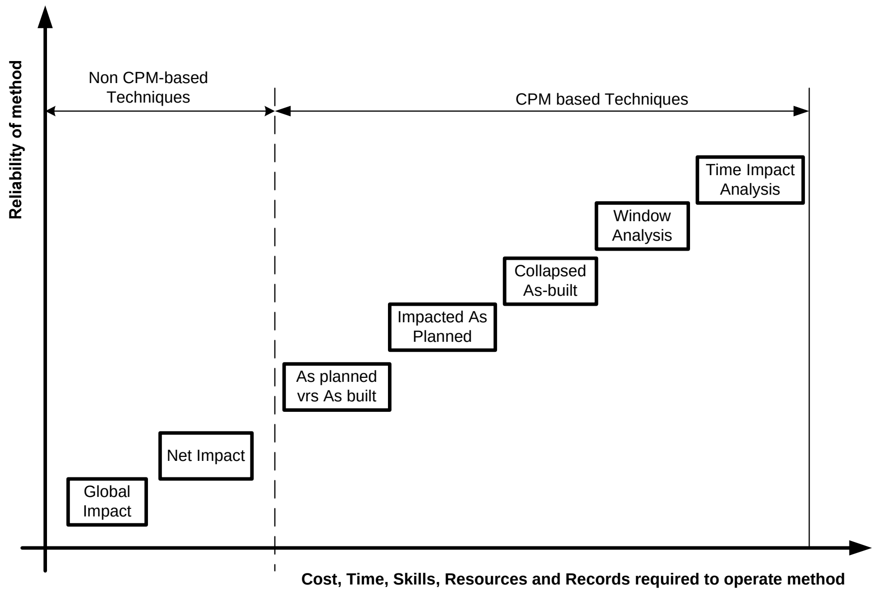

Figure 5.3 Characteristics of DAMs

5.3.2 Brief description of the various DAMs

Having highlighted the various differences between the methods, this section concentrates on how each is utilised including their strengths and weaknesses.

<u>The S curve</u>

This methodology analyses delay based on the relationship between cost and time. It involves developing a time/cost S-curve for the original plan together with the S-curve representing actual income. The actual S-curve must exclude any cost for additional works so that comparison of the two curves is valid. The amount of delay at any point along the actual curve is the horizontal distance between these curves at this point (Rubin *et al.*, 1999). The limitations of this technique are as follows:

it does not identify and track the activities on the critical path;

the original planned S-curve might not be accurate due to "front end loading" or other factors;

payments for stored materials and equipment could result in misleading progress of an updated S-curve.

Global Impact technique

This is a relatively simple approach of analysing the impact of delay on projects. All the delay events are first shown on a summary bar chart by determining their start and finish dates. The total project delay is then calculated to be the sum total of the durations of all delaying events (Alkass *et al.*, 1996; Pinnell, 1998; Bramble and Callahan, 2000). Though this technique provides a simple and clear statement of the amount of delay that is incurred, it has a major limitation: it does not consider concurrent delays and the actual delay types that took place presuming that all delays automatically caused project delay.

Net Impact technique

This is an improvement on the preceding methodology to deal with the problem of concurrency. Under this technique, all delays are plotted on an as-built bar chart schedule where the actual durations, start and finish dates of activities are shown (Leary and Bramble, 1988). By this, only the net effect of all the delays is depicted and the amount of delay to the project is the difference between the as-planned and the as-built completion dates. The limitation of the methodology is that it does not scrutinize delay types and could lead to overstatement of the amount of delays having an effect on the project completion date (Alkass *et al.*, 1996).

The major limitation common to the above three methodologies is that because CPM network is not used, float, criticality and interdependencies of activities are not readily apparent making it difficult to determine the true impact of delays. For this reason, the use of these methodologies is generally discouraged by most practitioners (SCL, 2002; Wickwire and Groff, 2004).

<u>As-planned vs. As-built</u>

This methodology simply compares the activities of the original CPM baseline schedule with those of the as-built schedule for detailed assessment of the delays that occurred. The main advantages of this methodology are that: it is relatively inexpensive, simple and easy to use or understand (Lovejoy, 2004). Its limitations include failure to consider changes in the critical path and inability to deal with complex delay situations (Stumpf, 2000; Zack, 2001).

<u>Impacted As-planned</u>

This methodology involves incorporating delays encountered as activities into as-planned CPM schedule to demonstrate how a project completion date is being delayed by those delays. The amount of project delay due to each delaying event is the difference between the schedules completion dates before and after the addition (Trauner, 1990; Pickavance, 2005). Although this methodology does not need an as-built schedule to operate, it has major drawbacks such as failure to consider any changes in the critical path and the assumption that the planned construction sequence remains valid (Stumpf, 2000; Zack, 2001; Wickwire and Groff 2004).

Collapsed As-built

This methodology first creates an as-built CPM schedule including all the delays encountered. Delays are then removed from the schedule to create a ‘collapsed’ as-built schedule, which indicates how the project would have progressed but for those delays. The advantage with this approach includes producing results of good accuracy (Lovejoy, 2004). Its limitations, however, include: ignoring any changes in the critical path and the great deal of effort required in identifying the as-built critical path (Zack, 2001).

Window Analysis

In this methodology, the total project duration as given by as-built CPM schedule is first divided into a number of time periods or ‘windows’. The dates defining the boundaries of these windows are often determined by major project milestones, significant changes in the critical path, occurrence of major delay events and dates for the issue of schedule revisions or updates. These factors determine the number and durations of the windows for the whole project duration. The more windows there are or the shorter their durations, the better the accuracy of the analysis (Finke, 1999; Hegazy and Zhang, 2005).

The delay analysis begins first by updating the schedule within the first window using as-built information including all the delays encountered in that period, while maintaining the remaining as-planned schedule beyond this window. The difference between the project completion date of the schedule resulting from this and that prior to the review process gives the amount of project delay as a result of the delays within the first window. This analysis is repeated successively for each of the remaining

windows to determine the effect of all other delay events on project completion. The main strength of this methodology is its ability to take care of the dynamic nature of the critical path. However, it is usually more expensive due to the amount of time and effort needed to perform it (Zack, 2001).

Time Impact Analysis

This methodology is a variant of the window technique described above, except that in this, the analyst concentrates on a specific delay or delaying event not on time periods containing delays or delaying events (Alkass *et al.,* 1996). The approach evaluates the effects of delays chronologically, starting with the first delay event, by incorporating each delay (sometimes using a 'fragnet' or sub networks) into an updated CPM baseline schedule that represents the actual status of the project before the advent of the delay. The amount of project delay caused by each of the delaying events is successively determined by computing the difference between project completion date of the schedule resulting from the addition of each delay and that prior to the addition. This approach developed out of its original purpose of prospectively analysing, on an ongoing basis, the effects of changes to the project. Prior to the 1980s, this traditional use of Time Impact Analysis was a requirement in some US federal government contracts (Wickwire, *et al*., 1989; Wickwire *et al.*, 1991). The approach has significant merit making it probably the most reliable technique (SCL, 2002). However, it is time consuming and costly to operate, particularly in situations where large number of delaying events are involved.

5.3.3 Appropriate use of the methodologies

The different set of procedures and assumptions required by each methodology, have resulted in them producing different results of staggeringly different levels of accuracy for any given claims situation (Alkass *et al.*, 1996; Bubshait and Cuningham, 1998; Stumpf, 2000). In addition, there is currently no industry-wide agreement on which is the most appropriate methodology to use for delay claims analysis. This is evident by the diverse views among researchers and practitioners on four common methodologies as shown in Table 5.2 (compiled by Arditi and Pattanakitchamroon (2006)). The series of debates organised by SCL, dubbed "Great Delay Analysis Debate", which was first presented to an audience of over 300 in London and subsequently in Scotland, USA and Dubai also bear testimony to such different views. These debates involved four participants each speaking in favour of one of the four common methodologies with reference to a hypothetical construction scenario. Voting is subsequently carried out as to the most appropriate methodology that should be applied to the assumed facts. In the London debate, for instance, no consensus was reached as to the correct method, with votes splitting into four significant minorities (SCL, 2006).

Table 5.2 Comments on DAMs compiled from the literature (1987–2004) (source: Arditi and Pattanakitchamroon, 2006)

References	**Delay analysis methods**			
	As-planned vs. As-built	Impacted As-planned	Collapsed As-built	Time Impact Analysis
Sandlin et al.(2004)	N/A	Spurious results	Erroneous evaluation	Overcomes some disadvantages of others
Lovejoy (2004)	Fair	Good	Excellent	Very good
Sgarlata and Brasco (2004)	Worthy method	N/A	Most acceptable by courts	Useful for prospective analyses, but minimal utility supporting claims
Gothand (2003)	Major drawbacks	Major drawbacks	Major drawbacks	Reliable
SCL (2002)	Simple, limited	Simple, limited	Suitable for some situations, subjective	Most reliable when available
Harris and Scott (2001)	Least popular	N/A	Fair, most accepted	Make some use by claims consultants
Zack (2001)	Critical flaws	Critical flaws	Unreliable, easy to manipulate	Accurate but expensive
Stumpf (2000)	Can be challenged	Easy to prepare, fundamental flaws	Easy to prepare, fundamental flaws	Reliable, but time consuming
Fruchtman (2000)	Reliable	Simple, limited	No baseline needed, limited	Contemporaneous basis, but no future changes considered
Finke (1999) and (1997b)	N/A	Less reflective of actual events	Less reflective of actual events	Most reasonable and accurate
Zack (1999)	Unreliable	Many flaws, widely discarded	Suitable	Suitable
McCullough (1999)	Not acceptable	Not acceptable	Useful in some situations but easy to manipulate	Dependent on baseline schedule, accurate
Bubshait and Cunningham (1998)	Acceptable, dependent on availability of data	Acceptable, dependent on availability of data	Acceptable, dependent on availability of data	Acceptable, dependent on availability of data
Levin (1998)	N/A	Simple, consistently rejected by courts	Dependent on quality of as-built schedule	Dependent on how the method is applied
Alkass et al. (1996)	N/A	Some major problems	Sound, but ignores changes of critical paths	Some drawbacks/propose modified method
Zafar (1996)	Reliable	Fault analysis	Fault analysis	N/A
Schumacher (1995)	N/A	Potential shortcoming, one-sided analysis	Overcome some shortcomings	Effective method
Baram (1994)	Dependent on	Dependent on	Most practical in some circumstances	Most desirable approach
Wickwire et al. (1991)	N/A	“Great lie”	Alive and well	Recommended
Bramble and Callahan (1987)	Acceptable, dependent on availability of data	Acceptable, dependent on availability of data	Acceptable, dependent on availability of data	N/A

Due to these different perceptions, the appropriateness of the methodology applied in producing a delay claim is therefore often hotly contested. For example, in *Balfour Beatty Construction Ltd v The Mayor and Burgesses of the London Borough of Lambeth (2002 1 BLR 288),* the defendant challenged the adjudicator's decision in court for, among others, not having given any opportunity to the parties to comment on the appropriateness of the methodology which the adjudicator had adopted in determining extensions of time and to seek their observations as to its use. His Honour Judge Humphrey Lloyd QC stated that the adjudicator ought to have informed both parties of the methodology that he intended to adopt and sought their observations on its appropriateness. He held that, in the light of such serious omissions, he could not uphold the decision. Similarly in *Try Construction Limited v Eton Town House Group (2003) EWHC60 (TCC),* the defendant challenged the Adjudicator for using a methodology that it did not have a chance to consider.

The factors that influence the selection of the appropriate methodologies are therefore a matter of the greatest importance. Notwithstanding this, the UK courts have not generally gone into any great depth as to what method of proof is acceptable in particular circumstances or, when a method of analysis has not been accepted, the reasons for its rejection (Pickavance, 2005). A review of delay analysis literature disclosed only three major initiatives aimed at developing knowledge and understanding of the way analysts should select from existing DAMs for any given delay problem. First, Bubshait and Cuningham (1998) assessed the reliability of three of the existing methods using a case study and came to the conclusion that none of the methods is perfect and that the best method should be chosen based upon the time and resources available and the accessibility of project documentation. Second, in a survey

by Harris and Scott (2001) on how UK professionals deal with claims, respondents were generally unwilling to indicate their preference to four existing DAMs, with the reason that their choice would be dictated by the conditions of the claims at hand. The study, however, did not investigate the conditions that they consider important in this respect. Finally, the SCL's protocol (2002) has identified a number of factors that analysts should look out for in considering a methodology. These are: the relevant conditions of contract; the nature of the causative events; the value of the dispute; the time available; the records available; the programme information available and the programmer's skill level and familiarity with the project. Similar factors have also been reviewed recently by Arditi and Pattanakitchamroon (2006).

From the foregoing, the general view has been that no single methodology is suitable for all claims situations and that the most appropriate methodology for any situation should be selected based on a number of factors or criteria. These criteria, as reported in the literature, are shown in Table 5.3. Although these can help in the selection of appropriate DAM, the limitation is that they are qualitative, subjective and imprecise in nature, making their use in methodology selection open to challenge. The absence of acceptable guidelines or standards for assisting practitioners in the use of these criteria in methodology selection means that analysts' choice will often be made based on methodologies that will suit their respective positions. This is a potential source of disputes requiring that more attention be given to it.

Table 5.3 Factors influencing the selection of DAM (Braimah and Ndekugri, 2007)

Factor	Literature source						
	Leary and Bramble (1988)	Colin and Retik (1997)	Finke (1997b)	Bubshait and Cunningham (1998)	Bramble and Callahan (2000)	SCL (2002)	Pickavance (2005)
Records availability	✓	✓	✓	✓	✓	✓	✓
Baseline programme availability	✓			✓		✓	✓
Nature of baseline programme				✓	✓	✓	✓
Updated programme availability				✓	✓	✓	✓
Reason for the delay analysis	✓	✓					✓
Applicable legislation		✓					
The form of contract		✓	✓			✓	✓
Cost of using the technique	✓			✓		✓	✓
Nature of the delaying events	✓				✓	✓	
Skills of the analyst	✓				✓	✓	
The amount in dispute	✓					✓	
The number of delaying events			✓		✓		

5.4 Disruption Analysis Methodologies (DSAM)

Unlike pure delay, disruption analysis involves the claimant proving that inefficiencies or loss in productivity were suffered as a result of delays and/or disruptions complained of. Analysing project disruptions for proper quantification and allocation of the lost productivity is, however, often recognised as a difficult undertaking (Schwartzkopf, 1995; Ibbs, 1997). A major reason for the difficulty is the inherent complicated nature of labour productivity, which varies due to variability of human responses to different working conditions. The conditions can be either task-related factors, such as type of work being performed, the resources assigned and the means and method used to perform the task, or non-task related (external) such as

crowding, adverse weather, out-of-sequence work, etc. These are often attributable to multiple events and project participants (Leonard *et al*., 1988; Hanna and Heale, 1994). As Zink (1990) puts it: *The responsibility for lost efficiency rarely rests with one side or the other of the claim. It is generally recognized that some fault for labour inefficiency will rest with both parties.* The event sometimes occur simultaneously making it more difficult to unravel and sort out clearly what is often a tangled web or 'spaghetti' of interrelated issues and problems into their individual causes and effects.

There are various methodologies available for analysing disruption. Like DAMs, most of these methodologies are referred to by different nomenclature among practitioners as shown in Table 5.4.

Table 5.4 Existing DSAM

Common name	Alternative names
Total Cost (Brunies, 1988; Kallo; 1996a; Finke, 1998a;Bramble and Callahan, 2000; Jones, 2001; Klanac and Nelson, 2004)	**Global method** (SCL, 2002; Pickavance, 2005) **Rolled up claim** (Pickavance, 2005)
Modified Total Cost (Brunies, 1988; Kallo; 1996a; Bramble and Callahan, 2000; Jones, 2001; Klanac and Nelson, 2004)	**Adjusted Total cost** (Brunies, 1988)
Measured Mile Technique (Zink, 1986, 1990; Schwartzkopf *et al*., 1992; Schwartzkopf , 1995; SCL, 2002; Jones, 2001; Klanac and Nelson, 2004; Pickavance, 2005)	**Differential Cost Method/Calculation** (Brunies, 1988; Moselhi et al. 1991) **Productivity Comparison Method** (Shea, 1989); **Measured Productivity Method** (Wickwire *et al*. 1991; Bramble and Callahan, 2000) **Comparison of Productivity Levels** (Kallo; 1996a) **Cause-and-Effect Method** (Kallo; 1996a) **Differential Studies** (Klanac and Nelson, 2004)
Industry Studies and Guidelines (Klanac and Nelson, 2004)	**Estimating** (Brunies, 1988) **Estimated Evaluation Method** (Shea, 1989); **Productivity Factors** (Kallo; 1996a) **Factor-Based Methods** (Finke, 1998a) **Trade Publications** (Bramble and Callahan, 2000) **Model Productivity Curves and Factors** (SCL, 2002) **Industry Standards** (Schwartzkopf *et al*., 1992)
Jury Verdict (Kallo; 1996a; Jones, 2001; Klanac and Nelson, 2004)	
Time and Motions Studies (Pickavance, 2007)	
Earned Value Management (Schwartzkopf, 1995; McCally, 1999) **System Dynamic Modelling** (Ackermann *et al*., 1997; William *et al*., 2003; Cooper *et al*., 2004; Eden *et al*., 2004)	**Earned value analysis** (Boyle, 2007)

The following defines and discusses each of the methodology with respect to how they are employed and their strengths and weaknesses.

5.4.1 The Measured Mile Technique

This method compares actual productivity of impacted operation with actual productivity achieved while doing the same work but in an un-impacted mode (Zink, 1986). By this, control figures come from the project itself eliminating disputes over the validity of cost estimates, or factors that may have impacted productivity due to no fault of the employer. The standards that have to be satisfied for the appropriate use of this method include (Brunies, 1988; Loulakis and Santiago, 1999):

- the work performed during the mile should be substantially similar in type, nature, and complexity to the work that was affected;
- the composition and level of skill of the crews should be comparable;
- the measured mile should represent reasonably attainable labour productivity levels;
- the difference between the actual productivity of the affected items and the 'normal' productivity resulted solely from the causes under examination;
- the "normal" productivity of the unaffected items allows for all applicable risks and/or inherits shortcomings of the contractor and represents a sufficiently high percentage of the item(s) of work under examination to generate reasonable confidence in the comparison.

Although theoretically the measured mile technique appears simple, there are a number of shortcomings affecting their use in practice including:

- considerable amount of investigation required to establish the cause-and-effect relationship prescribed by this method (Brunies, 1988; Ibbs and Liu, 2005);
- the analysis will generally be based on calculations performed after the fact making it inapplicable for prospective analysis of disruption particularly when negotiating changes.
- the assumption that the future progress of the project will be a linear extrapolation of the measure mile (Zink, 1986);
- it may be difficult to find un-impacted parts particularly when disruptions to the work are so pervasive (Ibbs and Liu, 2005).

5.4.2 Industry Studies and Guidelines

Researchers and various organisations such as the US Corps of Engineers, National Electrical Contractors Association of America, Mechanical Contractors' Association of America (MCAA) have developed factors and statistical model of productivity curves for estimating productivity losses. These have been developed for productivity factors like overtime, overmanning, weather, learning curve and change orders. The advantage of this method over the others is that it allows a prediction of the most likely losses when negotiating changes prospectively. It is also very useful in evaluating lost productivity resulting from multiple impacts by enabling the analyst to isolate certain impact events and assign a particular value to that event (Klanac and Nelson, 2004). However, its limitations include:

- the data collection of these studies were limited to specific project environment and to a number of specific trades thus raising questions on their general applicability;

the sources of the data for some of the studies are not revealed suggesting that they may be anecdotal and judgemental (Ibbs, 2005);

the quality of the data in respect of some studies are doubtful, for example, that of the overtime charts produced by MCAA and AACE (Brunies and Emir, 2001);

the objectivity of most of the guidelines are questionable because they were developed by parties with vested interests without the involvement of the other project party; and

Most of the guidelines are silent on how they should be properly used as terms such as "minor" and "severe", which are subjective, are not defined in the guide (e.g. the MCAA guidelines).

5.4.3 Total Cost Method

Under this method the claimant entitlement is estimated as the difference between the actual cost and the contractual cost without establishing any causal link between the reason for their entitlement and the quantity of the corresponding loss. It can thus hide losses not caused by the employer such as those resulting from the contractor's own poor project management or bidding errors. This has been its main criticism making it the least favoured method. However, because construction projects can generate very complex set of interacting activities, which are impossible or impracticable to separate into their individual causes and effects, there has been a long-standing debate over the acceptance or rejection of claims produced using this method. Earlier UK cases dealing with global claims are: *J. Crosby & Sons Ltd v Portland Urban District Council (1967) 5 BLR 121* and *London Borough of Merton v Stanley Hugh Leach Ltd (1985) 32 BLR 51.* The common interpretation of these cases is that where it may be

difficult to make accurate apportionment of the total claims, it may be proper for an arbitrator to make individual financial awards in respect of claims which can conveniently be dealt with in isolation and a supplementary award in respect of the remainder of these claims as a composite whole (Brown, 1995; Gaitskell, 2003). However, the Privy Council's decision in the Hong Kong case of *Wharf properties Ltd and Another v Eric Cummins Associates and Others (1991) 52 BLR 8,* in which the pleading was struck out due to the failure of the claimant to particularise it, has been interpreted by some as a set back in the judicial approval of the global claims approach. Following this decision, employers facing global claims often ask tribunals to strike them out. Subsequent cases, however, suggest that the courts have been more reticent about such applications although they do not accept incomplete claims. In the cases of: *Mid Glamorgan County Council v J Devonald Williams & Partners (1992) 8 Con LJ 61*; *Imperial Chemical Industries Plc v Bovis Construction Limited and Others (1992) CILL 776;* and *British Airways Pension Trustees Ltd v Sir Robert McAlpine & Sons Ltd* (1994) *72 BLR 31,* the judges rejected the defendant's application to strike out the claims which were pleaded on global basis.

The decision in the most recent case of *John Doyle Construction Ltd v Laing Management (Scotland) Ltd (2004) BLR 295* further reinforces the lenient stand taken by the courts on global claims. Laing were management contractors who employed Doyle as works package contractors in respect of the construction of a new corporate headquarters for Scottish widows. Doyle's claim for an extension of time plus loss and expense was made on global basis giving the reason that it was not possible to particularise it. Laing therefore sought to have the claim as pleaded struck out before trial but the judge allowed it to proceed to trail. Detailed analysis of the decision is not within the ambit of this thesis but a common interpretation has been that the decision

is to a greater or lesser extent an encouragement of the global claims approach. This case was approved by the TCC in *Skanska Construction UK Ltd v Egger (Barony) Ltd 2004 EWHC 1748 (TCC)*. The court held that global claims would be valid provided all the delays were caused by the defendant. Reflecting on the various cases, the current position on global claims in the UK can be summed-up as follows:

- Claimants are required to establish separately the causal link between each causal event and each amount of claim, although such separation may be difficult.
- The inability of the claimant to objectively identify each of the financial consequences of each and every event giving rise to the claim does not allow the responsible party to escape paying the damages.
- A global claim is likely to fail if the defendant's events causing the alleged loss are shown to be not significant.

On the contrary, the conditions for the acceptance of global claims are more explicitly defined in the US. These conditions, identified based on US courts decisions include satisfying the following proof (Brunies, 1988; Kallo, 1996a; Finke, 1998a):

- the contractor's tender or estimate was reasonable;
- the actual cost is fair and reasonable under the circumstances;
- the contractor must established that it was not responsible for any part of the increased cost;
- there is no other practical method available to quantify the damages with reasonable degree of accuracy.

5.4.4 Modified total cost approach

This method is similar to the total cost except that in this approach the contractor's bid estimate is adjusted to account for activities that were underbid or deemed to be his responsibility. The total cost differential is thus modified to eliminate cost factors that are the responsibility of the contractor and also correct inaccuracies in the original estimate. This makes the approach a more reliable method than the total cost method. In certain instances, the project is reanalysed retrospectively to determine what the project should have cost as a baseline instead of relying on the original estimate or its adjusted value. The method is correctly termed "should have approach" in such a situation (Shea, 1989).

5.4.5 Jury Verdict

This method affords the courts and other triers-of-fact (e.g. arbitrators) the discretion to determine recoverable disruption damages. They usually use evidence submitted in support of other quantification methods such as the total cost method and industry standards to derive a jury verdict calculation (Kallo, 1996a; Bramble and Callahan, 2000). Therefore unlike the other methods, this methodology is not available for contractors to use in making claims. The main weakness of it has been owners contending the approach to be nothing more than a guess regarding what the contractors damages are and freeing the contractor from its normal and customary burden of proving damages (Shea, 1989). The approach is often seen as last resort when there is clear evidence of entitlement to compensation but the amount of damages to be awarded have not been shown with specificity (Klanac and Nelson, 2004). This method is not applicable in the UK but in the US.

5.4.6 Time and Motion Studies

Although this approach is commonly used in the manufacturing industries for checking the efficiency of the work method, equipment used, and the worker, its application in construction claims is relative new. It was employed effectively and approved by the court in the US case of *Peter Kiewit Sons' Co. v. Summit Construction Co. 422 F.2d 242 (8th Cir. 1969).* The method involves determining the amount of time model activities should reasonably take to accomplish in like conditions based on an analyst making sample observations as to how work is performed on site (Pickavance, 2005). Contractors claiming for productivity loss may consider setting up such studies to measure increases in labour costs and equipment inefficiencies. All conditions experienced by the contractor on the job together with the conditions attributable to disruption should be simulated preferably at the actual job site if possible.

5.4.7 System Dynamics Modelling Approach

System dynamic models, widely used in various disciplines of project management, has also found application in the prove of DD claims (Ackermann *et al*., 1997; William *et al*., 2003; Cooper *et al*., 2004; Eden *et al.*, 2004). In this application, cause and effect structure of a dynamic model is developed and the mechanism by which project disruption occurs is traced. The model simulates, day by day, the unfolding of the project so that the impact of events at one stage of the project feed forward to their longer-term consequences. A particular significance of this model is the ability to replicate the impact of vicious cycles caused by management mitigation actions taken to accelerate the project (Eden *et al.*, 2004). It also allows a wide variety of "what if" scenarios to be assessed. However, the use of it in practice is limited because they

require significant time from experience modelers to execute (Cooper *et al*., 2004). This is partly due to the sophisticated nature of the method and the extensive research required in discovering the categories of events that disrupt or delay tasks on the project (Eden *et al.*, 2004).

5.4.8 Earned Value Management

Earned Value Management (EVM) is a cost control system that incorporates the organised components of the project's schedule, budget estimate and scope of work into a process by which the project's forecasted costs at the end of the project can be more readily determined (Fleming and Koppelman, 2002; Warhoe, 2004). To achieve this, EVM employs three dimensional measurement of project performance: the Budgeted Cost of Work Schedule (BCWS), Budgeted Cost of Work Performed (BCWP) and Actual Cost of Work Performed (ACWP). These dimensions are often shown in cumulative curves on the same diagram; both BCWP and ACWP curves are only shown as far the project has progressed over time. By overlaying these curves, a profile of changing cost and time is shown reflecting changes in resource levels, resource costs, activity durations, scope or logic changes.

To perform disruption analysis using EVM, changes in the forecasts, which are often due to reduction in productivity, are related to certain events using usual contemporaneous record sources. The difference between planned and actual productivity of the causative events in terms of earned value is then quantified (Schwartzkopf, 1995; McCally, 1999). The limitation of this methodology is that it relies on the availability of accurate progress and cost information, which are often not available.

5.4.9 Comments on the acceptability of the various DSAMs

The common aim of all the methodologies is to determine among others the reduction in productivity from what a contractor would have achieved but-for an employer-caused delay and/or disruption. However, the various methods attempt to accomplish this by different approaches as discussed in the previous section. The approaches vary mainly base on different sources of information they rely on for the analysis as indicated in Figure 5.4.

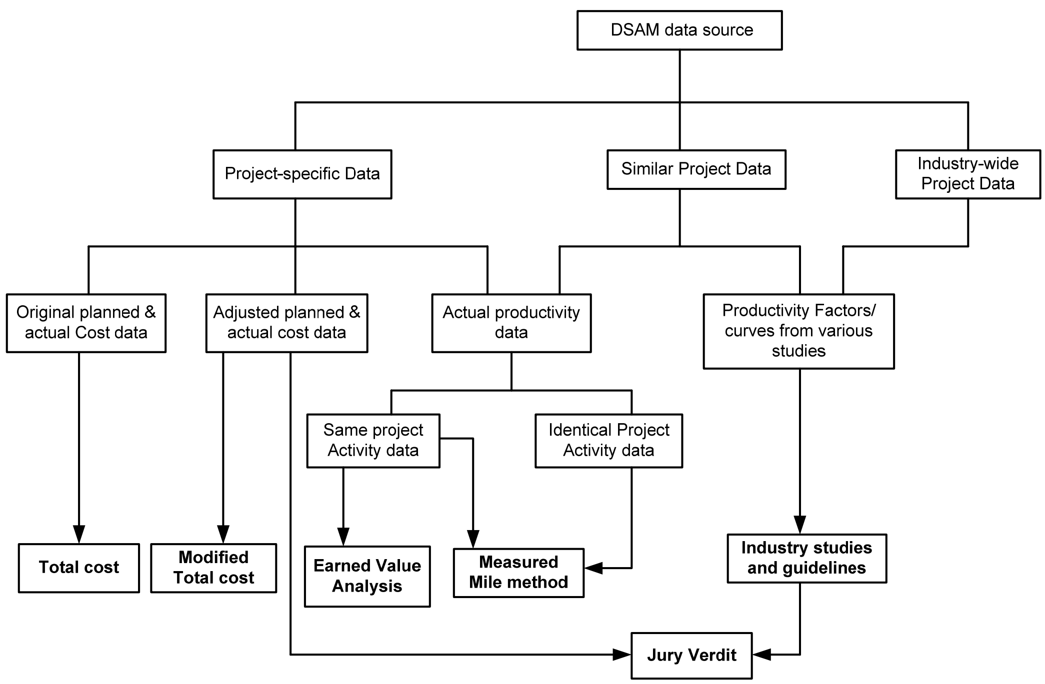

Figure 5.4 Sources of data relied on by various DSAMs

The strengths of the various methods differ depending on the nature and sources of the data relied on. As a result their use in a given claims situation generate different results of different levels of accuracy (Schwartzkopf, 1995). According to Schwartzkopf *et al.* (1992), no method is generally acceptable for use in all cases, although some are preferred over others. Table 5.5 shows a summary of the views of

researchers and practitioners on the most commented upon DSAM with respect to their acceptability or reliability. These were extracted from various research papers and text books published from 1988-2006 and thus gives a good representation of what is currently available on this subject with regard to the reliability of the methodologies. The authors' views on the methodologies are varied suggesting that none of the methodologies is perfect even though some are more reliable than others under certain circumstances. The views of most of the authors were based on US case law. In spite of this, the comments are quite relevant to UK practitioners because the requirement in proving cause-effect relationships does not substantially differ from the legal view point of the two countries.

It appears from the table that the most preferred or acceptable methodology is the Measured Mile technique while the least preferred methodology appears to be the total cost.

Table 5.5 Comments on DSAMs compiled from the literature (1987–2004)

References	Disruption analysis methodologies				
	Total cost	**Modified total cost**	**Measured Mile**	**Industry studies and guidelines**	**Jury verdict**
Brunies (1988)	Contractor's preference and acceptable if neither measured mile and estimating method cannot be used	Improved form of total cost approach	Classical approach	Most enlightened method for analysing disruption prospectively or retrospectively if the use Measured Mile is not practicable	N/A
Zink (1990), Norfleet (2005)	N/A	N/A	Some limitations; an improved version proposed	N/A	N/A
Shea (1989)	To be used as last resort	More accurate and preferable to Total Cost	Most acceptable method	Not as accurate as measured mile but useful in proving the existence of productivity losses	Acceptable if court finds claimants approach to be unacceptable
Schwartzkopf (1992)	The least widely accepted method but appears to be gaining acceptance by the courts	More reliable than total cost as it appears to be more readily accepted by the courts	Most widely accepted method	Do not give conclusive results	N/A
Kallo (1996a)	Generally viewed with scepticism and acceptable by the courts under strict conditions	More credible than Total cost method	Most acceptable method	Acceptable if its use is supported by corroborative evidence	Useful if contractor is clearly entitled to cost compensation but has no basis for the amount that is claimed.
Finke (1998a)	Major weakness but preferred by contractors	N/A	Preferred over total cost but can only be used retrospectively	They typically do not yield activity-specific results	N/A
Emir (1999)	Least favoured	Least favoured	Superior method	N/A	N/A
Jones (2001)	Acceptable based upon certain conditions	Next to measured mile in terms of reliability and judicial acceptance	Most acceptable approach	N/A	Least favoured; useful if causation is established but amount of damages cannot be ascertained with certainty
SCL (2002)	Rarely accepted by the courts	N/A	Most appropriate method	Might be acceptable if measured mile approach cannot be used	N/A
Presnell (2003)	Inaccurate method	Inaccurate method	Most credible and widely accepted	Inaccurate method	N/A
Gulezian and Samelian (2003)	Do not consider causal factors for which the owner is not responsible	Considers causal factors	Based on actual cost data	Not based on the project about which a claim is made	Educated guess based on available information in the absence of more reliable evidence

Table 5.5 Cont.

Klanac and Nelson (2004)	Significant shortcomings so should be a last resort method	Significant shortcomings so should be a last resort method	Most reliable	Has certain inherent problems but has positive applications	Useful if other methods are not available but entitlement is clear
Eden *et al*. (2004)	N/A	N/A	Most popular but unreliable; proposed system dynamic approach		
Ibbs and Liu (2005)	N/A	N/A	Some limitations; proposed improved version	Somewhat useful	
Pickavance (2005)	Permissible if it is impracticable to segregate the claims from other construction cost	More acceptable than total cost	Most widely accepted method	Useful in costing a variation prospectively. For guidance only when used in retrospective analysis	N/A

5.5 Summary

This chapter has reviewed the relevant literature on methodologies for analysing DD claims. The review covered many aspects of these methodologies including: their differences, how they are use, their strengths and weaknesses and factors affecting their use. The appropriate use of these methodologies in DD claims was also highlighted. The findings from the review are summarised as follows:

(a) There are a number of methodologies available for analysing delays and these are known by different terminologies among practitioners and researchers. The methodologies differ from each other based on the type of schedule techniques required, the baseline schedule used and the mode of application in their use. They produce different results of staggeringly different levels of accuracy when applied to a given claims situation.

(b) None of the methodologies is perfect as each has its own strengths and weaknesses. The more sophisticated methodologies are regarded as more reliable than the simplistic ones, though the former requires more expense, time, skills, resources and project records to operate than the later.

(c) No single DAM is universally acceptable for all claims situations. The most appropriate methodology for any given situation depends on a number of factors. Even though these factors have been identified by practitioners and researchers as essential for the selection of a methodology, they are qualitative, subjective and imprecise in nature, making their use in methodology selection open to challenge.

(d) Like DAMs, the methodologies for analysing disruptions are many and referred to by different names amongst practitioners. They vary based on the different sources of information each methodology relies on for the analysis.

(e) Similar to DAMs, none of the DSAM methodologies is perfect even though some are more reliable than others under certain circumstances. Their acceptability or reliability depends upon the situation of the disruption claims at hand.

The above findings formed the basis of the empirical study into the current use of these methodologies by industry practitioners. The study employed a nationwide-survey and its results are reported in the next chapter.

CHAPTER SIX

6 SURVEY ON METHODLOGIES FOR ANALYSING DD CLAIMS

6.1 Introduction

This survey employed two separate questionnaires in collecting data on DD claims analysis practice from contracting and consulting organisations across the UK, although the outline of these questionnaire were similar. Detailed information on the design of the questionnaire, research questions it addresses and sampling of the organisations are presented in Chapter 2. The questions contained in the questionnaire were informed by the review of the literature reported in Chapters 3, 4 and 5. This chapter presents the results and analyses the responses to individual questions in the light of comments made on DDA by researchers and experts. The rest of this chapter was written, grouping these under the following headings: (i) Survey response (ii) Characteristics of the respondents and their organisations (iii) Timing of DD claims submissions and assessment (iv) Extent of disputes on DD claims (v) Reasons for disputes over DD claims (vi) Involvement in DDA (vii) Perceptions on DAMs – level of awareness, use and reliability, obstacles to their use and factors influencing their selections (viii) Perceptions on DSAMs- level of awareness, use, and reliability. Most of these sections were considered separately for contractors and consultants.

6.2 Survey response

Out of the 300 questionnaires sent out, a total of 156 questionnaires were returned of which only 130 (63 from Contractors and 67 from consultants) were properly completed that could be used for analysis. The other 26 respondents stated either that it was company policy to decline to respond to surveys or have little experience in DD

claims analysis. This represents a response rate of 21% and 22% respectively for construction and consulting firms, which is within the expected range of (20-40)% typical of similar surveys (Furtrell, 1994).

6.3 Characteristics of the respondents and their organisations

Tables 6.1 and 6.2 respectively shows the distribution profile of respondents' organisations in terms of type and size and their designations for the construction and consulting firms. The response from construction organisation was fairly uniformly distributed over three main contracting groups, with those involved in both building and civil engineering projects having the greatest percentage followed by those involved in only civil engineering projects. The lowest percentage came from those involved in only building projects.

Table 6.1 Construction organisation response

Type of organisation	**Percent***
Building contracting only	27.0
Building and Civil Engineering contracting	39.7
Civil Engineering contracting only	33.3
Organisation Annual Turnover (£m)	
<5	7.9
5 – 25	25.4
26 – 100	30.2
>100	36.5
Respondent designation	
Planning Engineer	15.9
Commercial Manager /Quantity Surveyor	50.8
Project/Site Manager	9.5
External Claims Consultant	6.3
Managing Director	11.1
Contracts Director	6.3

* of the total response from construction firms

On the other hand, the response from consulting organisations was nonuniformly distributed with majority coming from quantity surveying and claims consulting firms. Engineering and Architectural firms were not well represented. This low response is probably because they do not actively carry out most delay claims assessments by themselves as discussed in later section of this chapter.

Table 6.2 Consulting organisation response

Type of organisation	**Percent***
Firm of Architects	9.0
Firm of Engineers	14.9
Firm of Quantity Surveyors	41.8
Firm of claims consultants	34.3
Organisation Annual Turnover (£m)	
<5	43.3
5 – 25	32.8
26 – 100	9.0
>100	14.9
Respondent designation	
Planning Engineer	3.0
Project Quantity Surveyor	35.8
Project Architect/ Engineer	25.4
External Claims Consultant	29.8
Managing Director/ Partner	6.0

* of the total response from consulting firms

With regard to the size of the organisations, four groups were identified based on their annual turnovers. Whilst this shows that the survey covered a wide spectrum of construction organisations, the distribution of the responses was not uniform. The average annual turnover of the organisations was £55million suggesting that the views sought were from medium to large construction organisations.

The designations of the respondents cover a wide variety of professions, which are relevant to DD claims analysis. The majority of them have been acting as Commercial Managers or Quantity Surveyors for employers and contractors with some occupying senior management positions.

Table 6.3 shows their experiences with regard to a number of relevant functions.

Table 6.3 Experience of respondents

Function	Years of experience						Mean years	Std. dev
	0	1-5	6-10	11-20	21-30	>30		
Construction organisations								
Estimating	12	22	16	5	5	3	8.0	9.3
Planning and Programming	12	12	20	9	8	2	9.7	9.2
Site Management	11	10	22	8	8	4	10.7	10.1
Measurement	9	17	6	11	13	7	13.4	11.9
Claims preparations	0	7	12	24	15	5	16.6	9.1
Contacts Management /Legal support	8	4	10	23	10	8	15.6	10.7
Consulting organisations								
Estimating	14	17	17	9	5	5	9.4	10.2
Planning and Programming	7	21	18	12	5	4	9.9	9.4
Site Management	19	22	18	4	3	1	5.7	7.1
Measurement	15	10	15	14	5	8	11.6	11.3
Claims preparations/ assessment	4	9	12	19	14	9	16.3	10.4
Contacts Management /Legal support	4	7	9	25	15	7	16.5	9.4

As can be seen, the average years of experience on claims preparation /assessments is the highest (over 16 years). This suggests that most of the respondents have been dealing with claims for considerable number of years and thus were ideally suited to comment on the issues dealt with in the survey. The average years of experience of measurement was higher than scheduling and site management, reflecting the fact that

the largest category of respondents was made up quantity surveyors or commercial managers by profession.

6.4 Timing of DD claims submissions and assessment

Timely submission of DD claims by contractors and their quick assessment by employers (or their representative) in the course of the project or as close in time to the occurrence of the delaying events is often recommended as a good practice (Ibbs and Ashley, 1987; Vidogah and Ndekugri, 1998; SCL 2002). The reason is that such practice ensures less difficult claims resolution because facts of the claims will be fresh in mind at that stage and also persons with little involvement in the actual project whose participation tend to complicate the claims settlement will be precluded. To investigate the extent to which this practice is observed by contracting parties, respondents were asked to score their level of agreement with the proposition: *"the analysis and resolution of most DD claims are left unresolved until nearer the end of the project or after completion before resolving"*; using a 5-point Likert scale (where '1= disagree' to '5 =agree'). Table 6.4 shows the results, which suggest that over 60% of the respondents from either construction or consulting firms are in agreement with this proposition.

Table 6.4 The proposition that most DD claims are resolved nearer project completions or after

Extent of agreement scale	Construction		Consulting	
	Percent	Cumulative Percent	Percent	Cumulative Percent
Strongly disagree	3.2	3.2	7.5	7.5
Disagree	9.5	12.7	9.0	16.4
Neutral	12.7	25.4	14.9	31.3
Agree	42.9	68.3	44.8	76.1
Strongly agree	31.7	100.0	23.9	100.0
Total	100.0		100	

The results suggest that contracting parties still face considerable difficulties in resolving DD claims at close in time as possible to the occurrence of the delaying events during the course of projects.

6.5 Extent of disputes on DD claims

As mentioned earlier on, claims relating to projects DD are often recognised as a major source of disputes in the construction industry. To confirm the validity of this as a justification (or otherwise) for the need to seek for improvement in current DDA practice, respondents were asked to score their level of agreement with the proposition: *"the resolution of DD claims are often attended by considerable difficulties thereby causing disputes"*, using a 5-point Likert scale (where "1= disagree" to "5 =agree"). Table 6.5 shows the results, which suggest that over 70 percent of the respondents are of the opinion that DD claims often result in disputes. This implies that DD claims resolutions continue to pose great challenge for project employers and contractors. Thus, there is still much to do in this subject area before matters of project DD can be resolved without much dispute.

Table 6.5 The proposition that most DD claims resolutions results in disputes

Extent of agreement scale	Construction		Consulting	
	Percent	Cumulative Percent	Percent	Cumulative Percent
Strongly disagree	6.3	6.3	7.5	7.5
Disagree	7.9	14.3	9.0	16.4
Neutral	12.7	27.0	13.4	29.9
Agree	49.2	76.2	49.3	79.1
Strongly agree	23.8	100.0	20.9	100.0
Total	100.0		100.0	

6.6 Reasons for disputes over DD claims

An important consideration in the design of a framework for improving DD analysis is identifying the reasons that often cause disputes over DD claims. In this respect,

respondents were asked to rate the frequency by which a number of reasons have each been the cause of disputes or unsatisfactory resolution of DD claims, using a five-point scale (where "1= not frequent" to "5 =very frequent"). Participants were also asked to add to the list and rate any other reasons they consider important. Table 6.6 shows a summary of the results.

Table 6.6 Reasons for dispute over DD claims

Reasons	**Contractors**		**Consultants**		**Overall**	
	Frequency index	**Rank**	**Frequency index**	**Rank**	**Frequency index**	**Rank**
Failure to establish causal link	76.1	1	81.1	1	78.8	1
Inadequate supporting documentation on quantum	67.7	2	72.2	2	70.1	2
Insufficient breakdown of claim amount	62.0	3	70.1	3	66.2	3
Conflicting interpretation of contractual provisions	54.2	4	59.7	5	57.0	4
Contractual provisions not properly identified to support claim	46.6	5	63.0	4	55.1	5
Inadequate effort at mitigation	37.4	8	59.0	6	48.6	6
Lack of timely notice	42.3	6	53.3	7	47.9	7
Inadequate/incorrect notice	40.0	7	50.6	8	45.5	8

Test Statistics

Kendall's W = 0.95

$\chi^2_{critical}$ (=0.05) = 14.07; df = 7; χ^2_{sample} = 864.5

As can be seen, the three most likely sources of disputes are: failure to establish causal link, inadequate supporting documentation on quantum and insufficient breakdown of claim amount. These issues therefore require much attention in researches aimed at reducing disputes on DD claims. There was a very high degree of agreement among the groups in their rankings, which was significant at 95% confidence level.

Brief commentary on the top three factors are as follows.

6.6.1 Failure to establish causal link

The ranking of this as the most frequent reason for DD claims dispute was not unexpected as proving cause-effect, i.e. linking the resulting damages of delays and/or disruptions with specific events, is difficult and immensely complicated process, particularly in matters where more than one event or party has contributed to the delay in a number of ways (Bramble and Callahan, 2000; Furst, 2006). Despite this difficulty, clear demonstration of the link between cause and effect remains an essential ingredient that has to be present for the DD claims to succeed (Bramble and Callahan, 2000; Pickavance, 2005). There is therefore the need for more attention on the various approaches available for establishing causal relationships in DD claims. The high ranking of the factor also suggests that either existing approaches contain many flaws or are wrongly applied or certain conditions prevent the proper establishment of the proof of causation.

6.6.2 Inadequate supporting documentation on quantum

The ranking of this factor as the second most frequent reason for disputes over DD claims suggests that failure to maintain adequate records of project activities and their cost is still a major problem. The construction industry has long been criticised on this problem (Kangari, 1995a; Ndekugri, 1996; Vidogah and Ndekugri, 1998). A major source of this problem is the use of improper systems for documenting or capturing accurate and complete record of job conditions. For instance, the cost coded accounting systems of most contractors are designed in such a way that base contract works and inefficiency components are intertwined (Fayek, 2001; Harris and

Ainsworth, 2003). In this way, clear delineation of cost attributable to each delay and/or disruptive event becomes difficult making it extremely difficult to substantiate the proper value or quantum of a claim. Although it is very expensive to effectively maintain adequate records on a contract, it is important that this is weighted against valid claims which may be substantially reduced or rejected outright because they lack proper documentation.

6.6.3 Insufficient breakdown of claim amount

Inability to breakdown the claim amount for each of the event complained of was ranked third. Claims suffering from this inadequacy are often referred to as ‘global’ or ‘rolled-up’ claims although most US practitioners use the term ‘total time claims’ for claims relating to time only. The most common view on global claims is that advancing such claims is a high-risk strategy and thus claimants should endeavour to separately quantify the claims amount for each causal event, although such separation may be difficult. Further description on global claims and its acceptability is reported in Chapter 5.

6.7 Involvement in DD claims Preparation and Assessment

The issues to be dealt with as far as the analysis of claims on DD are concerned are complex, requiring an understanding of contract law, contract forms, contract administration, project planning techniques, and an appreciation of how construction activity typically takes place (Scott *et al*., 2004). This multi-disciplinary nature suggests that a variety of people with various expertises would have to work together in a team to ensure adequate analysis and settlement of DD claims. Respondents were thus asked to rank the level of involvement of relevant experts in their organisations

in DD analysis on a five-point scale from “very low” (=1) to “very high” (5). Tables 6.7 and 6.8 give a summary of the results for construction and consulting firms, respectively. There was a strong and significant degree of agreement among the respondents in their rankings (as given by W= 0.74 and W=0.61 at =0.001).

Table 6.7 Level of involvement contractors’ staff

Expertise	**Involvement index**	**Rank**
Commercial Manager/Quantity Surveyor	86.1	1
Contractor’s Project /Site Manager	69.1	2
Head of Planning Dept. or his/her Nominee	57.8	3
External claims consultant	53.6	4
Head of Estimating Dept. or his/her Nominee	50.8	5
External lawyer	42.0	6
In-house lawyer	30.7	7
Test Statistics	Kendall's W = 0.74 χ^2_{sample} = 327.22; with df = 6 $\chi^2_{critical}$ (=0.001) = 22.46	

Within construction organisations, commercial manager or QS scored the highest degree of involvement followed by the project manager or site manager. This suggests that DA is still the domain of commercial managers although, with the development of user-friendly project planning software, programmers/schedulers appear to be making a significant contribution.

For consulting organisations, the employer’s QS scored the highest degree of involvement. This position stands in stark contrast to the provisions in most construction contracts that the obligation of assessing contractors’ claims is the responsibility of A/E. This finding corroborates previous study by Vidogah and Ndekugri (1998), in which most architects claimed that they often pass on claims to

QS for evaluations. However, such delegation is not stipulated in most contracts. An issue of concern though is that this can place much administrative burden on the employer and the contractor in the management of DD issues, as they may have to deal with more than one party. Another issue is that unless the QS is an in-house personnel (which is often not the case except perhaps in large employers), who is not fully occupied with other duties, there is the risk that enough time would not be available for claims assessment to be given the attention that it deserves.

Table 6.8 Level of Involvement of employers' consultants

Expertise	**Involvement rank index**	**Rank**
Project's quantity surveyor	80.0	1
Project's Architect /Engineer	74.9	2
External claims consultant	60.7	3
External lawyer	51.0	4
Client	40.0	5
In-house lawyer	35.5	6
Test Statistics	Kendall's W = 0.61 χ^2_{sample} = 288.33; with df = 5 $\chi^2_{critical}$ (=0.001) = 20.52	

The low involvement of client staff is understandable in the sense that A/Es are often contracted to administer the works including claims assessment responsibility as pointed out earlier on. However, the problem with this is the irony of the fact that the very virtues that render their appointment as delay claims assessors appropriate, such as their familiarity with the claims matter, serve to create conflict of interest particularly when dealing with delay events caused by their own failings like late issue of information, for example. This can result in unfair assessment of the claims thereby inhibiting settlement rather than facilitating it.

The involvement of construction lawyers received the lowest ranking from all the groups. This low involvement may be explained by the relatively high engagement of external claims consultants (ranked 4th by contractors and 3rd by consultants) who often possess relevant legal knowledge. Lack of input of experts with such knowledge can be detrimental for claims that require considerable legal justifications such as when proving the reasonableness of the A/E behaviour and assessing as to weather the contractor used ‘best endeavours’ to mitigate delays.

6.8 Perceptions on existing DAMs

6.8.1 Level of Awareness of the methods

An important consideration that can affect the use or implementation of any DAM is its level of awareness among practitioners. Respondents were thus first asked to rank their level of awareness of the various methods on a five-point scale from “unaware” (=1) to “very aware” (=5). Table 6.9 shows a summary of the results obtained.

The As planned vrs As-built methodology received the highest level of awareness for contractors, consultants and overall. The methodology with the lowest level of awareness was the Window analysis followed by the S-curve. Generally, construction firms seem to be more aware of the simplistic methods (Global, Net impact, As-planned vrs As-Built) than the sophisticated methods (Impacted as-planned, Collapsed as-built, Window analysis and Time impact analysis). An opposite trend was observed for consulting firms. Professional background and training may have influenced this result because consulting firms seem to rely more on the services of claims consultants (see Tables 6.7 and 6.8), who are the specialists in this subject, and thus

likely to be well-informed on existing sophisticated methods for resolving claims. There was a significant degree of agreement among the groups in their rankings on the extent of awareness.

Table 6.9 Level of awareness of the methods

Methodology	Contractors		Consultants		Overall	
	Awareness index	Rank	Awareness index	Rank	Awareness index	Rank
As planned vrs. As Built	86.4	1	86.3	1	86.3	1
Impacted as-planned	79.6	3	77.6	3	78.6	2
Global	79.9	2	75.7	4	77.8	3
Net impact	72.9	4	74.5	5	73.8	4
Collapsed as-built	59.6	5	70.3	6	65.1	5
Time impact Analysis	46.4	6	78.2	2	62.9	6
S-Curve	40.9	7	68.8	7	55.2	7
Window analysis	40.0	8	67.2	8	54.0	8

Test Statistics

Kendall's W = 0.87

$\chi^2_{critical}$ (=0.05) = 14.07; df = 7; χ^2_{sample} = 791.7

6.8.2 Extent of use of the methods

To investigate the practical applications of the various DAMs, respondents were asked to rank the extent of use of the methods using the 5-point scale from “low” (=1) to “high” (=5). A summary of the results is presented in Table 6.10. The degree of agreement (W) among the groups in ranking was computed as 0.50 which was significant at =0.05. There was thus significant degree of agreement among contractors and consultants on the extent of use of each of the existing methodologies.

As-planned vrs As-built was ranked 1st by contractors and overall although it ranked was 3rd by consultants. Collapsed as-built was rather the most widely used techniques

of the consulting firms. Generally, the simplistic methods are more popular with construction firms than the consulting firms. This is consistent with the findings of previous studies that the simplistic techniques are more commonly used in practice by contractors (Bordoli and Baldwin, 1998; Harris and Scott, 2001; Kumaraswamy and Yogeswaran, 2003). Possible reasons responsible for their popularity are that they: are simple to use and understand; do not require complete project records, which are often lacking as Table 6.6 reveals, and require fewer resources to use (Alkass *et al.*, 1996; Lovejoy, 2004).

Table 6.10 Extent of use of the methods

Methodology	**Contractors**		**Consultants**		**Overall**	
	Usage index	**Rank**	**Usage index**	**Rank**	**Usage index**	**Rank**
As-planned vrs. As-Built	81.9	1	56.3	2	65.7	1
Impacted as-planned	70.2	2	54.1	3	59.4	2
Collapsed as-built	47.1	5	63.0	1	54.8	3
Time impact Analysis	37.5	6	52.5	4	48.2	4
Net impact	51.7	4	39.7	6	45.7	5
Global	54.6	3	36.7	8	45.5	6
Window analysis	31.4	7	48.9	5	40.2	7
S-Curve	30.2	8	37.2	7	33.8	8

Test Statistics

Kendall's W = 0.50

$\chi^2_{critical}$ (=0.05) = 14.07; df = 7; χ^2_{sample} = 455.0

6.8.3 Reliability of the methodologies in delay claims analysis

Most construction disputes in the UK are resolved by arbitration and other dispute resolution forums which are private in nature. This has resulted in the publication of far less decisions on the use of the various DAMs and therefore very little information

is available to practitioners as to their acceptability or reliability in practice. Therefore a section of the questionnaire sought to examine respondents' views on the reliability of the methodologies in terms of settlement of claims without disputes that require resolution by a third party. Two main aspects, complementing each other were studied: rating the level of claims' success associated with using each of the methods by rating them on a 1-5 scale (1 representing "low" and 5 is for "high"); and rating the extent of challenge posed by opposing parties to claims analysed using them on a similar scale from "never" (=1) to "always" (=5). A summary of the results is shown in Tables 6.11 and 6.12 for the success and challenge aspects, respectively.

Table 6.11 Level of success with delay claims analysed using the methods

Methodology	**Contractors**		**Consultants**		**Overall**	
	Success index	**Rank**	**Success index**	**Rank**	**Success index**	**Rank**
As planned vrs. As Built	80.3	1	53.6	3	66.0	1
Impacted as-planned	67.7	2	51.1	5	59.2	2
Collapsed as-built	49.6	4	52.2	4	50.9	3
Time impact Analysis	37.9	6	60.3	1	49.8	4
Window analysis	30.9	7	57.8	2	45.2	5
Net impact	54.1	3	33.5	7	43.4	6
Global	45.8	5	32.8	8	39.2	7
S-Curve	27.1	8	33.6	6	30.5	8
Test Statistics						
Kendall's W = 0.45						
$\chi^2_{critical}$ (=0.05) = 14.07; df = 7; χ^2_{sample} = 409.5						

The As-Planned vs. As-Built methodology was ranked by contractors as the most effective in ensuring success of claims followed by the Impacted As-Planned technique. This finding contradicts the opinions of some commentators that, on account of various shortcomings such as insufficient attention to the critical path and lack of capability to deal effectively with concurrency, acceleration and work re-

sequencing, they are considered unreliable (Stumpf, 2000; Zack, 2001; Pickavance, 2005). A possible explanation for this unexpected result may be due to the fact that they are the most widely used methodology (see Table 6.10), and are therefore likely to be the methods upon which most claims are finally resolved.

Consultants on the other hand ranked Time impact analysis followed by Window analysis as methods that ensure claims' successes without disputes, consistent with the views in the literature (for e.g. Bramble and Callahan, 2000; SCL, 2002). The W value obtained was 0.45, which was significant at 95% confidence level. There is thus significant degree of agreement among contractors and consultants as to the ranking of the methods with regards to their effectiveness in ensuring success of delay claims.

Table 6.12 Frequency of challenges to claims analysed using the methods

Methodology	**Contractors**		**Consultants**		**Overall**	
	Challenge index	**Rank**	**Challenge index**	**Rank**	**Challenge index**	**Rank**
Global	90.9	1	82.6	1	86.6	1
Net impact	75.3	2	78.4	2	76.9	2
As planned vrs. As Built	67.6	3	72.9	3	70.4	3
Impacted as-planned	64.7	4	67.3	6	66.0	4
S-Curve	52.0	6	71.8	4	62.3	5
Collapsed as-built	54.1	5	65.4	8	60.0	6
Time impact Analysis	46.9	8	67.6	5	58.3	7
Window analysis	48.5	7	66.0	7	57.9	8

Test Statistics

Kendall's W = 0.85

$\chi^2_{critical}$ (=0.05) = 14.07; df = 7; χ^2_{sample} = 773.5

On the frequency of challenge posed by opposing parties to delay claims resulting from the method used, the Global method received the overall highest score followed

by the Net Impact technique. This finding corroborates published commentaries (Alkass *et al.*, 1996; SCL, 2002). Generally, as had been expected, the sophisticated methods were ranked as less susceptible to challenge than the simpler methods, thus suggesting that the former are more reliable than the latter. There was a significant degree of agreement among the groups in their rankings given by W=0.845 at 95% confidence level.

6.8.4 Correlation between DAM rankings

As a means of validating the ranking results, further investigation was carried out to identify any relationship between the ranking results of awareness and use for each DAM on the one hand, and between success and challenge rankings for each methodology on the other hand.

Spearman Rank Order Correlation test was employed in identifying any existing relationships as shown in Appendix D. A summary of the results obtained is shown in Table 6.13.

Table 6.13 Spearman Rank Order correlations on DAMs rankings

Methodology	Construction		Consulting	
	awareness vrs. usage	Success vrs. Challenge	awareness vrs. usage	Success vrs. Challenge
S-Curve	0.576	0.274*	0.468	-0.352
Global	0.475	-0.174	0.375*	-0.298*
Net Impact	0.557	0.191*	0.228*	0.443
As-Planned vs. As-Built	0.676	-0.203*	0.198*	-0.366
Impacted As-planned	0.569	-0.056	0.410*	-0.256*
Collapsed As-built	0.676	-0.150*	0.277	-0.281*
Window Analysis	0.728	-0.442	0.431	-0.488
Time Impact Analysis	0.737	-0.505	0.289	-0.321*

* Significant at 0.05 level; all other correlations sig. at 0.01 level

Generally, there was a significant correlation between the rankings on awareness level and extent of use, suggesting that the methodologies are used to the same extent as their level of awareness. Similar results but negative were observed for that between the rankings on success and challenge, suggesting that the more a methodology is open to challenge, the less capable it is in ensuring success in claims resolutions.

6.8.5 Obstacles to the use of DAMs

Some commentators have sought to explain the relatively low use of some DAMs by pointing out perceived obstacles to their successful usage. To investigate the validity of these commentaries respondents were asked to score the perceived obstacles on the frequency with which they are encountered in practice on a 5-point Likert scale (where “1= not frequent” to “5 =very frequent”). Respondents were also asked to add and rate any other relevant obstacles not included in the listed. Table 6.14 shows the rankings of the obstacles obtained from analysis of the results. As indicated by the test statistics, the degree of agreement among the respondents in their ranking was strong and significant.

Discussions on the top five obstacles are as follows.

Table 6.14 Obstacles to the use of DAMs

Factors	Contractors		Consultants		Overall	
	Frequency index	**Rank**	**Frequency index**	**Rank**	**Frequency index**	**Rank**
Lack of adequate project information	75.9	1	76.4	1	76.1	1
Poorly updated programmes	74.4	3	73.0	2	73.7	2
Baseline programme without CPM network	67.5	5	69.9	3	68.7	3
High cost involved in their use	66.3	6	67.5	4	66.9	4
Difficulty in the use of the techniques	66.0	7	62.1	6	64.0	5
Lack of familiarity with the techniques	75.0	2	53.5	8	63.8	6
Unrealistic baseline programme	57.5	9	60.0	7	58.8	7
High time consumption in using them	52.0	10	64.5	5	58.6	8
Lack of skills in using the techniques	69.9	4	44.1	10	56.3	9
Lack of suitable programming software	65.7	8	47.5	9	56.2	10

Test Statistics

Kendall's W = 0.72

$\chi^2_{critical}$ (=0.05) = 16.92; df = 9; χ^2_{sample} = 842.4

Lack of adequate project information

The highest rank given to this factor corroborates commentaries on the poor quality of project records (Kangari, 1995a; Vidogah and Ndekugri, 1998) and the difficulty they pose to achieving the standard of proof required of delay claims (Jergeas and Hartman, 1994; Kangari, 1995a). Delay analysis carried out using any of the methods relies very much upon what actually happened on the project, which in turn requires the keeping of detailed site records. Lack of such records makes analysis at a uniform

level impossible. If the analysis is not uniform in approach some delays are likely to be concealed and others may be distorted or overemphasised resulting in inaccuracies.

Poorly updated programmes

The ideal way of proving delays is to determine the effect of individual delays on project as at the time that they occurred (Trauner, 1990; Finke, 1999). For this to be achievable, the schedule has to be maintained properly by updating it periodically to keep track of important information such as changes in the critical path, actual start and finish dates and percentage complete for each activity; reassessed activity durations; and logic changes from previous updates. The high ranking of lack of proper updated programme as 3rd by contractors and 2nd by consultants and 2nd by overall concurs with the views in the literature (Jaafari, 1984; Nahapiet and Nahapiet, 1985; Mace, 1990).

Baseline programme without CPM network

The power of CPM-based schedules for proving construction delay claims analysis can be traced back to the early 1970s in the United States (Wickwire *et al.*, 1989). Such schedules allow for the determination of critical path(s) and the interrelationships among multiple causes of delay (Wickwire *et al.*, 1989; Bramble and Callahan, 2000). A study by Aouad and Price (1994) showed that most contractors plan and manage construction projects using critical path planning methods. The high ranking of this factor was therefore unexpected. Possible explanations include that the CPM schedules are withheld from delay claims because they tend to contradict the contractor’s claim.

High cost involved in the use of the techniques

This factor was ranked 6th by contractors and 4th by consultants and overall. This was not unexpected because analysing delays using the various methods, particularly the complex ones can be very costly (Alkass *et al.*, 1996; Lovejoy, 2004). A major source of the cost is the carrying out of some form of thorough CPM analysis using the contract programme. In the absence of a reliable programme, retrospective reconstruction of CPM As-Built from project records may be required which is a highly laborious task requiring considerable levels of skills and experience. Although such analyses are costly, they tend to give more accurate results.

Difficulty in the use of the methods

It should be clear from the discussion so far that the preparation and negotiation of delay claims requires high levels of multi-disciplinary skills, particularly in the areas of scheduling, work methods, costing and information technology. The high ranking of difficulty in the use of the methods was therefore to be expected. Also, such ranking may be inferred from the high ranking accorded to unfamiliarity with the techniques, which was ranked 6th overall, 2nd by contractors and 8th by consultants.

6.8.6 Factors influencing the selection of DAMs

As highlighted in Chapter 5, the factors that influence the selection of the appropriate methodologies are a matter of the greatest importance. Respondents were thus asked to rank a number of factors identified from literature and the initial pilot studies, on a 5-point Likert scale (1 for “not important” and 5 for “very important”) on their degree of importance in their decision-making in DAM selection. Provision was also made for respondents to add and rate any other factor (s) they considered important.

The results, shown in Table 6.15, demonstrate that on the whole “record availability” ranks first followed by “baseline programme availability”, while “the other party to the claim” and “applicable legislation” comes at the bottom. The ranking of record availability as the most important factor was not unexpected because irrespective of the method adopted, analysts will have to depend on this for analysis, although the amount of records required varies for the various DAMs. A claimant or defendant will have a difficult time proving the standing of his or her case if documentary evidence is lacking (Jergeas and Hartman, 1994; Kangari, 1995a). Factors relating to the contract programme were generally ranked high by the groups and overall, suggesting that programmes have relatively high degree of influence on the method selected for DA. This was not surprising as programmes are now recognised as the main vehicle for analysing delays (Wickwire *et al.*, 1989; Kallo, 1996b; Conlin and Retik, 1997).

A remarkable observation is the high ranking of “The amount in dispute” as 4th, 5th and 3rd by contractors, consultants and overall, respectively. The possible reason for this is the fact that analysing delay claims can be costly and time-consuming process particularly when using methods such as Time Impact Analysis and Window Analysis (Alkass *et al.*, 1996; Lovejoy, 2004). This makes it necessary to consider the value of the claims in dispute in relation to the cost involved in resolving it to ensure the selection of a cost effective methodology.

By and large, there was a strong consensus among contractors and consultants in their rankings (W= 0.93) and this was statistically significant at 95% confidence level.

However, there was much difference in their ranking on skills of the analyst. Consultants ranked it 4^{th} while contractors ranked it 10^{th}, suggesting that contractors attach relatively less importance to analysts skills' in choosing a methodology. Considering that lack of appropriate skills would lead to results likely to be challenged, the relatively low ranking by contractors is surprising and needs further investigation. On the other hand, the high levels of disputes associated with delay may be a reflection of insufficient appreciation by contractors of the importance of delay analysis skills.

Table 6.15 Relative importance of DAM selection factors

Selection Factor	**Contractors**		**Consultants**		**Overall**	
	Important index	**Rank**	**Important index**	**Rank**	**Important index**	**Rank**
Records availability	99.7	1	95.5	1	97.5	1
Baseline programme availability	85.4	2	83.1	2	84.1	2
The amount in dispute	71.5	4	74.7	5	73.1	3
Nature of baseline programme	73.3	3	69.8	6	71.5	4
Updated programme availability	64.7	5	76.7	3	69.8	5
The number of delaying events	64.4	7	67.7	7	66.1	6
Complexity of the project	64.5	6	66.9	10	65.8	7
Skills of the analyst	54.0	11	76.1	4	65.3	8
Nature of the delaying events	64.4	7	64.7	12	64.6	9
Time of the delay	58.4	10	65.4	11	62.0	10
Reason for the delay analysis	60.6	9	67.2	8	61.8	11
Form of contract	50.7	13	67.2	8	59.2	12
Cost of using the technique	52.4	12	63.3	13	58.0	13
Dispute resolution forum	50.5	14	58.3	15	54.4	14
Size of project	42.3	16	59.1	14	50.9	15
Duration of the project	37.5	18	52.2	17	45.1	16
The other party to the claim	47.1	15	42.5	18	44.7	17
Applicable legislation	38.7	17	53.7	16	36.5	18

Test Statistics

Kendall's W = 0.93

$\chi^2_{critical}$ = 27.59 (=0.05); df = 17; χ^2_{sample} = 2055.3

6.8.7 Application of factor analysis to the selection factors

Table 6.16 shows the results of the factor analysis in a rotated principal component matrix. The 6 group factors extracted accounted for 69.18% of the common variance shared by all the 18 selection factors. The group factors were appraised to identify the underlying features that the constituent selection factors have in common. This resulted in the interpretation of the group factors as follows:

group factor 1-project characteristics;

group factor 2- requirements of the contract;

group factor 3-characteristics of baseline programme;

group factor 4-cost proportionality;

group factor 5-timing of analysis; and

group factor 6-record availability

Table 6.16 Principal Component Analysis Results

Selection factors	Components						Communalities
	Group factor 1	Group factor 2	Group factor 3	Group factor 4	Group factor 5	Group factor 6	
Complexity of the project	0.7962						0.6873
The amount in dispute	0.7243						0.5904
Size of project	0.6496						0.7904
Duration of the project	0.6407						0.8057
Nature of the delaying events	0.5253						0.6724
The number of delaying events	0.5021						0.7500
The other party to the claim	0.4102						0.6969
Updated programme availability		0.8102					0.6692
Applicable legislation		0.6938					0.6460
Form of contract		0.6910					0.6309
Dispute resolution forum		0.4949					0.6031
Nature of baseline programme			0.8453				0.7456
Baseline programme availability			0.7360				0.7739
Cost of using the technique				0.8106			0.6986
Skills of the analyst				0.6809			0.6306
Reason for the delay analysis					-0.5160		0.7009
Time of the delay					-0.5294		0.6121
Records availability						0.8373	0.7488
Eigenvalue	4.765	2.109	1.670	1.517	1.229	1.163	
Percentage variance	26.472	11.714	9.276	8.430	6.827	6.464	
Cumulative % variance	26.472	38.186	47.463	55.892	62.719	69.183	

Group factor 1: Project characteristics

This group factor accounts for 26.5% of the variance and is made up of complexity of the project, the amount in dispute, size of the project, duration of the project, nature of delaying events, number of delaying events and the other party to the claim. The loading together of these factors was not surprising as the literature also suggests that they are related. In research by Bennet and Fine (1980), complexity of a project activity was viewed as the nature of the combinations of a number of operations involved in the activity or the incidence of roles requiring different kinds of work identified as work packages. These operations are often innovative and conducted in an uncertain or not clearly defined situation (Malzio *et al.*, 1988). Gidado (1996) also identified overlap of phases or concurrency of activities as a component of project complexity.

The identified project characteristics often impact on the nature of the delays encountered (e.g. serial or concurrent of delays), thereby necessitating the use of certain DAMs to a greater extent than others. Methods involving the use of bar charts are unable to show critical paths, interrelationships and interdependencies between activities and therefore are not suitable for proving delays where changes in the construction logic were experienced and the effects of the delay were not restricted to clearly definable activities (Pickavance, 2005, p.503). Although methods such as As-Planned vrs As-Built and Collapsed As-Built utilise CPM techniques, they are unable to take into account concurrent delays and any changes in the critical path schedule during the course of the project (Alkass *et al*., 1996). These limitations make them unsuitable for delay situations where re-sequencing and acceleration took place in the course of the project.

Group factor 2: Contractual requirements

Contractual requirements grouping accounted for 11.7% of the variance and comprised availability of an updated programme, applicable legislation, form of contract and dispute resolution forum. These factors relate to the provisions or requirements of the project contract and can influence the methodology that should be used to analyse delays. For instance, contract clauses relating to programming and progress control requirements may have a bearing on the availability of contract programmes and its updates, which in turn facilitate the use of certain DAM to a greater extent than others. Furthermore, standard forms provisions in respect of providing relief from liquidated damages for employer risk events tend to fall into two main categories, which can influence the choice of DAM (SCL, 2002, p.46). The first category provides that contractors are only entitled to relief (in the form of extension of time) for events that actually cause delay to completion. Under this category, methods that seek to produce actual project delay such as the Collapsed As-built and As-Planned vrs As-Built may be suitable to use. For the second category, relief are to be granted for the likely effect of the events for the purpose of providing the contractor with a rough but realistic completion date pending final review. In this case, Impacted as- Planned or Time Impact Analysis may be appropriate (SCL, 2002, p.46).

Group factor 3: Characteristics of baseline programme

This group factor is made up of availability of baseline programme and the nature of the baseline programme and accounts for 9.3% of the variance in the selection factors. The baseline programme may not always be available or exist in CPM format, making certain methodologies more appropriate to use than others.

In the absence of an As-Planned programme or where significant part of it lacks sufficient detail, methodologies, which rely heavily on this programme cannot be readily used. In such a situation DAMs based much on As-Built programme may be more suitable. Although the As-Planned programme can be created or corrected retrospectively for the analysis, this hindsight development could easily be challenged on grounds of bias or unreliability (Trauner, 1990).

<u>Group factor 4: Cost proportionality</u>

This group factor includes cost of using the DAM and the skills of the analyst and account for 8.4% of the variance. It is noteworthy that the level of skills required in the application of the methods can influence the expense involved. For example, analysing complex delay claims often require the use of powerful planning software packages, which have functionalities and specialist features to facilitate the analysis (Conlin and Retik, 1997; Hegazy and El-Zamzamy, 1998). These packages are however, known to be relatively expensive, difficult to use, and require considerable effort in maintenance and amendments (Kelsey *et al.*, 2001; Liberatore *et al*., 2001).

A major source of the cost is the carrying out of some form of thorough CPM analysis using the contract programme. In the absence of a reliable programme, retrospective reconstruction of CPM As-Built from project records may be required which is a highly laborious task requiring considerable levels of skills and experience. Although such analyses are costly, they tend to give more accurate results. However, in a situation where the claim values are small compared to the cost involved in using a particular DAM, it may be appropriate to use a simple and less costly methodology for the analysis (Pickavance, 2005).

Group factor 5: Timing of the analysis

This group factor accounts for 6.8% of the variance in the selection factors and comprises the reason for the analysis and time of the delay. The purposes for analysing delay claims are many including: the resolution of matters concerning extension of time, prolongation cost, acceleration and disruption (Wickwire *et al*., 1989). These require different nature of proof because of their different requirements. For instance, the effect of disruption is often delay to progress or productivity loss and would only cause delay in completion if the impacted activities lie on the contractor's critical path. As a result methods utilising CPM should be considered when claiming for extensions of time for employer-caused disruptions. Concerning claims for reimbursement of loss or expense, the claimant should be able to prove the actual cost suffered, which warrants an approach based on what actually occurred on the project (Pickavance, 1997).

The time of the delay refers to the time of its occurrence relative to the stage of the project. In this respect, DA is carried out either prospectively or retrospectively of the delay occurrence. The former refers to analysing delays at its inception for the determination of their theoretical or likely impact on the programme. This is best undertaken using methodologies that largely do not require actual project data for their implementation such as the Impacted As-Planned method. Retrospective analysis, on the other hand refers to delays assessment after their occurrence or after the project is completed and methodologies such as Collapsed As-Built would be suitable as they are able to show what actually occurred.

The loading of reason for the analysis and time of the delay together under one group suggests that they are related. For instance, while extensions of time can be assessed prospectively it may not be appropriate to assess prolongation cost in this manner because many of the standard forms of contract require recoverable prolongation costs to be ascertained and not just estimated. Indeed, the *SCL Protocol* (SCL, 2002) emphasised that: *"……compensation for prolongation should not be paid for anything other than work actually done, time actually taken up or loss and/or expense actually suffered…"*

Group factor 6: Record availability

Record availability factor is the only selection factor in this group and accounts for 6.5% of the variance in the selection factors. The sources of information that are useful in DA includes contract documents, letters, minutes of meetings, notes, material receipts, supervision and inspection reports, resource data and costs, daily reports, extra work order, photographs, project schedules, and cost reports of a project (Cox, 1997, Pickavance, 2005). The extent of availability and reliability of these records may influence the methodology to be used, with less project information necessitating the use of the less sophisticated DAMs and vice versa (Lovejoy, 2004). The more reliable methodologies such as Window Analysis or Time Impact Analysis require the availability of more project information to operate and thus would produce less accurate results when important information is lacking.

6.9 Perceptions on DSAMs

As with the DAMs, the respondents were asked to rank the level of awareness, use and reliability of existing methodologies for analysing disruption claims using the 5-point Likert scale.

6.9.1 *Level of awareness and use of DSAMs*

As with the delay analysis methods, respondents were asked to rank their level of awareness of the methodologies a five-point scale from “unaware” (=1) to “very aware” (=5). Table 6.17 shows a summary of the results obtained. The test for significance results shows that there was significant agreement between the two groups in the ranking at 95% confidence level.

Table 6.17 Level of awareness of DSAMs

Methodology	Contractors		Consultants		Overall	
	Awareness index	**Rank**	**Awareness index**	**Rank**	**Awareness index**	**Rank**
Global Method	76.2	1	79.0	1	80.6	1
Modified Global Method	71.3	2	69.5	2	70.4	2
Measured Mile Technique	61.6	4	66.1	3	66.2	3
Industry Studies and Guidelines	63.7	3	63.8	4	63.5	4
Time and Motion Studies	46.1	6	56.7	6	55.1	5
Earned Value Management	48.7	5	57.4	5	53.1	6
Systems Dynamics	27.0	7	38.7	7	32.9	7
Test Statistics						
Kendall's W = 0.98						
$\chi^2_{critical}$ (=0.05) = 12.59; df = 6; χ^2_{sample} = 764.4						

The most well known methodology is the Global method, followed by the Modified Global method. This high level of awareness could be due to the fact that the Global method has gained much attention of researchers and expert commentators than the others as review of the literature suggests. The chances for practitioners to learn or hear about it have therefore been very high. The methodologies with least level of awareness are the Systems Dynamics, Earned Value Management and Time and Motion Studies, in that order.

Table 6.18 shows the results on extent of use of the methodologies as ranked by respondents on the Likert scale from "low" (=1) to "high" (=5). There was a significant degree of agreement between contractors and consultants on this at 95% confidence level.

Table 6.18 Extent of use of DSAMs

Methodology	**Contractors**		**Consultants**		**Overall**	
	Usage index	**Rank**	**Usage index**	**Rank**	**Usage index**	**Rank**
Modified Global Method	62.3	2	56.8	1	58.8	1
Global Method	65.3	1	54.5	2	50.9	2
Industry Studies and Guidelines	46.7	3	52.3	3	49.5	3
Measured Mile Technique	45.5	4	48.0	4	46.8	4
Earned Value Management	36.4	5	39.0	5	37.7	5
Time and Motion Studies	32.6	6	35.5	6	34.0	6
Systems Dynamics	23.9	7	28.4	7	26.1	7

Test Statistics

Kendall's W = 0.925

$\chi^2_{critical}$ (=0.05) = 12.59; df = 6; χ^2_{sample} = 721.5

As can be seen, the methodologies reported to have numerous weaknesses are surprisingly the most widely used. Contractors for example, ranked the Global method 1st followed by Modified Global method and vice versa for consultants. The extensive use of these methodologies could be explained from lack of accurate and proper project documentation, reported as the most frequent problem to claims resolutions (see Tables 6.6 and 6.22). This makes the use of more accurate methods impossible as they require such records for their implementation.

Conversely, the Measured Mile Technique, regarded by most practitioners as the most accurate technique (see Table 5.5), is not widely used as it ranked 4th. Amongst the least used methodologies were the Earned Value Management, System Dynamics and Time and Motions studies although these are also mentioned in the literature as more accurate than the Global method, Modified Global method and Industry Studies/guidelines (Schwartzkopf, 1995; McCally, 1999; William *et al*., 2003; Cooper *et al*., 2004).

6.9.2 The reliability of DSAMs

The various DSAMs were also assessed with respect to the level of claims' successes and challenges associated with their use using the 5-point scale. A summary of the results on these is shown in Tables 6.19 and 6.20, respectively. The degree of agreement between the groups in their rankings was high (W=0.68 and W=0.92) and significant at 95% confidence level.

On the whole, the Measured Mile technique, followed by the Modified Global Method and Industry Studies and Guidelines, were ranked as the most reliable in ensuring successful claims resolution without disputes. The System Dynamics and the Time and Motion studies ranked 6th and 7th respectively on this suggesting that they are not reliable. This was unexpected as they are reported to be more accurate, at least, than the Global Method, Modified Global Method and the Industry Studies/Guidelines (Schwartzkopf, 1995; William *et al*., 2003; Pickavance, 2005). The reason for the low ranking of System Dynamics and the Time and Motion studies could be due to the fact that they are the least used methodologies (as Table 6.18

suggests), which thus devoid most practitioners of information on their success rate in practice.

Table 6.19 Level of success with disruption claims analysed using the methods

Methodology	Contractors		Consultants		Overall	
	Success index	**Rank**	**Success index**	**Rank**	**Success index**	**Rank**
Measured Mile Technique	51.9	2	56.0	1	54.8	1
Modified Global Method	54.6	1	42.0	5	48.0	2
Industry Studies and Guidelines	46.5	3	49.2	3	47.8	3
Earned Value Management	39.2	5	51.7	2	45.7	4
Global Method	41.0	4	37.7	7	40.0	5
Systems Dynamics	27.0	7	46.0	4	36.6	6
Time and Motion Studies	33.7	6	39.0	6	36.4	7

Test Statistics

Kendall's W = 0.68

$\chi^2_{critical}$ (=0.05) = 12.59; df = 6; χ^2_{sample} = 530.4

With regard to the frequency of challenge these methodologies expose claims to, the Global Method received the highest rank followed by the Industry Studies/Guidelines and the Modified Global Method. This was expected given their continued criticisms by the courts and practitioners, particularly the Global method (Finke, 1997; SCL, 2002; Klanac and Nelson, 2004). On the other hand, the Measured Mile Technique followed by the Time and Motion Studies and then the Earned Value Management ranked as the most reliable on this aspect. This corroborates with the views of researchers and expert commentators presented in Chapter 5.

Table 6.20 Frequency of challenges to claims analysed using the methods

Methodology	Contractors		Consultants		Overall	
	Challenge index	**Rank**	**Challenge index**	**Rank**	**Challenge index**	**Rank**
Global Method	71.1	1	69.1	1	70.8	1
Industry Studies and Guidelines	68.7	2	61.9	3	65.9	2
Modified Global Method	59.6	3	65.1	2	63.5	3
Systems Dynamics	58.4	4	55.7	7	57.0	4
Earned Value Management	55.2	5	58.3	5	56.9	5
Time and Motion Studies	54.4	6	58.6	4	56.5	6
Measured Mile Technique	52.2	7	56.1	6	54.1	7

Test Statistics

Kendall's W = 0.92

$\chi^2_{critical}$ (=0.05) = 12.59; df = 6; χ^2_{sample} = 717.6

6.9.3 Correlation between the rankings of DSAMs

Like the DAMs, Spearman Rank Order correlation was used to compute the correlations between the rankings on awareness level and extent of use of each DSAM on the one hand; and between Success and challenge rakings of each methodology on the other hand (see Appendix D for detailed results).

A summary of the results is shown in Table 6.21. As can be seen, significant positive relationship exists between the rankings on awareness level and extent of use for the groups suggesting that the methodologies are used to the same extent as their level of awareness. The correlation between success and challenge were largely negative and significant, suggesting that as a methodology is open to challenge, there is a corresponding decrease in success rates of claims settled using them.

Table 6.21 Spearman Rank Order correlations on DSAM rankings

Methodology	Construction		Consulting	
	Awareness vrs.Usage	Success vrs. Challenge	Awareness vrs.Usage	Success vrs. Challenge
Measured mile technique	0.419	-0.182	0.341	-0.303*
Industry studies and charts	0.584	-0.231	0.768	0.227*
Global method	0.737	-0.156	0.256*	-0.133
Modified global method	0.641	0.205*	0.430	0.212
Systems dynamics	0.679	-0.303	0.656	-0.042
Earned value management	0.840	-0.521*	0.547	-0.459*
Time and motion studies	0.701	0.295	0.201*	0.419

* Significant at 0.05 level; all other correlations sig. at 0.01 level

6.10 General comments on the problems responsible for DD analysis difficulties

To confirm and identify further sources of difficulties affecting DD analysis**,** respondents were asked to provide general comments on what they think are responsible for poor resolutions of DD claims. Although not all the respondents replied to this open question, the majority who answered did so enthusiastically by stating at least two problems.

The comments offered are summarised and grouped under eight headings as tabulated in Table 6.22. Similar views were expressed by both the contractors and consultants. The main problems identified relates to poor record keeping, inadequate programming practice, unhelpful attitude of employers and lack of expertise with relevant skills and experience for dealing with DD claims. These findings corroborates the earlier results on causes of disputes and obstacle to the use of DD analysis methodologies, confirming that poor programming and record keeping practice as the major sources of problems responsible for the difficulties and disputes on DD claims resolutions.

Table 6.22 Problems responsible for poor resolutions of DD claims

Factor	Frequency
Project records	
Lack of clear, accurate/reliable and adequate contemporaneous records	22
Difficulties on agreeing on the level of information needed	4
Lack of productivity norms for individual contracting organisations	2
Lack of attention to facts with too much emphasis on the type of analysis to be	2
Poor information by subcontractors	1
Inability to keep up with the logistics of keeping accurate records	1
Attitude of project employer/owner	
Lack of understanding from the client of disruptive effects of changes	6
‘All risk’ contracts not properly expressed	3
Basic dislike of ‘claims’ by client	2
Reluctant by client teams to recognised liability because of budget constraints	2
Client does not want to be shown lacking	1
Adversarial relationship between claims parties	
Parties having entrenched views and protecting their perceived positions	7
Parties’ failure to acknowledge their contribution to DD and accept responsibility	4
Lack of commitment to seeking recompense due to client relationship risk	1
Personnel and expertise to deal with claims	
Lack of experience, knowledge and skills of claims resolvers	8
People/staff leaving construction companies	2
Lack of consistency in approach within the industry	2
Employers team not versed in contract requirements	1
Attitude of employers’ Architect/Engineer	
Lack of timely decisions by Architects/Engineers regarding delays	6
Architects/Engineers do very little in mitigating delays	3
Insufficient thought given to the outcome or likely outcome of changes	2
Planning and programming	
Lack of proper planning and management of the project	5
Contractor’s baseline programmes not reliable/realistic	3
Most contractors do not update their programmes	2
DD notice	
DD claims are usually left unresolved until the end of the project	3
Lack of timely notifications by contractors	2
Resources	
Lack of resources to risk-manage claims on site	2
Cost of employing delay analysis experts	2

6.11 Summary

This chapter has presented the results of a questionnaire survey of contractors and consultants aimed for establishing the current practice in the use of DDA methodologies and their associated problem. The survey questionnaires were distributed to 600 construction organisations across UK and received an overall response rate of 21%, representing 63 responses from construction organisation and 67 from consulting organisations. The respondents were mostly from medium to large construction organisations with considerable experience in claims evaluations. Various statistical tests including frequencies, relative indices, Kendall's Concordance, Chi-square tests, correlations and factor analysis were used to analyse the survey data. There was a considerable corroboration between the study results and the findings of the literature review. A summary of the findings of the survey is as follows:

(a) The majority of the respondents agree that DD claims are often left unresolved until nearer the end of the project or after before resolving. Also, majority agree that DD claims resolutions are often attended by considerable difficulties resulting in frequent disputes.

(b) The main reasons for disputes over DD claims are failure to establish causal link, inadequate supporting documentation on quantum and insufficient breakdown of claim amount suggesting that there are deficiencies in current record keeping and programming practice which require more attention.

(c) The preparation and assessment of DD claims often require input from commercial managers (quantity surveyors), schedulers, site managers, architects/engineers, external claim consultants, lawyers and estimators.

(d) Commercial managers or quantity surveyors have the greatest involvement in either claims preparation within construction firms or its assessment by employers' consulting team. The highest input from QSs within consulting firms conflicts with the provision in most forms of contract that the Architect/Engineer is responsible for claims assessments. The expert with the lowest involvement was construction lawyers.

(e) On the whole, the three most well known methodologies for analysing delay claims are the As-Planned vs. As-Built, Impacted as planned and Global method, whilst the least known are the Window analysis and the 'S' curve.

(f) Extent of usage generally corresponds to the degree of awareness of the methodologies. Although the popular methods are the most prone to challenge they are also those that most frequently lead to winning claims because of the relatively very low usage of the most accurate techniques.

(g) The main obstacles to the use of DAMs are lack of adequate project information, poorly updated programmes and baseline programme without CPM network, confirming the earlier results on reasons for disputes over DD claims. Again, record keeping and programming

practice are the areas that need further attention if improvements in DD analysis are to be achieved.

(h) A total of 18 selection criteria were identified as relevant in influencing the selection of delay analysis methodology. These criteria have different rates of importance with the top five as records availability, baseline programme availability, the amount in dispute, nature of baseline programme, and updated programme availability.

(i) On the methodologies for analysing disruption claims, the most well known and widely used methods are the Global method, Modified global method and Industry studies and guidelines, although they are known to have major weaknesses. The least used methodologies are System Dynamics and Time and Motion studies.

(j) The Measured Mile Technique and the Earned Value Management were perceived as the most reliable methodologies for analysing disruption claims although these methods are not highly used in practice.

In conclusion, the main difficulties with DD claim resolutions and the ensuing disputes are due to poor record keeping and programming practices which have led to wide use of less vigorous DD analysis methodologies that are incapable of producing accurate and less challenging claims results. The next phase of the research entailed the use of semi-structured interviews for investigating issues of programming in more depth within construction organisations. The results of the investigation are reported in the next chapter (Chapter 7).

CHAPTER SEVEN

7 INTERVIEW RESULTS ON PROGRAMMING ISSUES

7.1 Introduction

The findings of the postal survey in the previous chapter indicate that much of the issues affecting proper DD analysis relate to programming and record keeping practice of construction organisations. Therefore, to properly understand why the most reliable DD methodologies are not widely used in practice, interviews on programming matters were further conducted among some of construction firms who responded to the survey. The issues investigated include baseline programme development, management of these programmes, productivity records keeping and progress reporting. This chapter reports the findings of this investigation.

Out of the 63 construction firms who responded to the postal survey, 15 agreed to take part and did so enthusiastically. The method of analysis adopted involved the following. First, responses from each interviewee were recorded for each question successively to form a database. This database was then carefully examined to identify emerging themes which were collated using frequency analysis into summary results.

The rest of this chapter presents and discusses the results obtained under the following headings: (i) baseline programme development (ii) involvement in programme development (iii) resource loading and levelling (iv) programme updating (v) progress reporting and (vi) keeping records of crew productivity.

7.2 Baseline programme development

Interviewees were asked to rate the frequency by which their organisation prepare and submit baseline programme to the employer or its representative for approval or acceptance on a five point Likert scale from "never" (=1) to "always" (5). Table 7.1 shows the response.

Table 7.1 Extent of submission of baseline programme

Interviewee	Scale				
	1	**2**	**3**	**4**	**5**
1				✓	
2					✓
3				✓	
4			✓		
5				✓	
6					✓
7				✓	
8				✓	
9			✓		
10					✓
11				✓	
12				✓	
13					✓
14		✓			
15					✓
Percentage (%)	0	6.7	13.3	46.7	33.3

Respondents were asked to mention the programming technique they often use in preparing their baseline programmes. All respondents mentioned linked bar charts as the format they usually employ for most of their projects. They went further to give various reasons why this is often used as follows:

Easy to prepare and use (80%)

Easy to read and maintain (77.3%)

Company policy (62.1%)

Clients' request (52%)

It is able to show critical path and activity relationships (55%)

With this, a question was put to respondents on how they view the use of traditional CPM network (arrow or precedence diagramming methods). The majority replied that the linked bar chart is a form of a network diagram, which has a more easy to read appearance like Gantt chart and therefore do not see why traditional CPM network diagram should be used. One respondent noted: "*I would not say most contractors and clients will struggle with network diagrams, but is not the norm these days. I can't remember the last time we used a network diagram"*. Another commented: *"Company culture is programming using linked bar chart. It is the technique we have been using over the years and is able to do the job without problems."*

Although the linked bar chart tries to incorporate the good qualities of bar charts, such as being simple to understand, with the logic relationships of CPM, its main weakness is that it can generate "link maze" (i.e. activity links crossing over each other in a complex a network). This can lead to difficulties in identifying the relationships between individual activities. It can also make it difficult to show a link to an activity that does not start at its earliest time.

Therefore for projects involving complex sequence of activities the use of the linked bar chart would be unsuitable. Most modern construction projects are likely to involve such complex sequencing. It can therefore be concluded that the low rate of use of sophisticated DAMs such as Time Impact Analysis in practice is probably because most contractors do not programme their works using CPM which has the capability of showing clearly all activity relationships.

On the tool they use to develop the programme, all respondents mentioned that they use computers and mentioned the following software packages as the most common ones they have been using.

CS Project (31%)

Power Project (31%)

MS Project (23%)

Asta Teamplan (15%)

These packages have been criticised for their indiscipline task logic and not being very rigorous in their performance of forensic analysis of project records when analysing delays (Conlin and Retik, 1997; Hegazy and El-Zamzamy, 1998; Liberatore *et al*., 2001). *Primavera*, which is very popular software in the US and also recognised by most experts as very versatile in programming and forensic scheduling analysis, was not reported as widely used. Only one respondent claimed that they do occasionally use (very rarely) it and this is when their client specifies that it should be used. Although some hail this package for being in-depth and robust, they gave reasons for not using it as: relatively very expensive, very complex and requires a lot of time in setting it up.

In addition to the baseline programme, interviewees mentioned that they also develop a number of programmes for managing the project. The following (Table 7.2) shows the programmes indicated by respondents as often developed for most of their projects. As can be observed, manpower loading graph is among the less-frequently developed plans. The implication of this is that it would be difficult to resource-load/level baseline programmes as evident in Section 7.5.

Table 7.2 Other preconstruction planning deliverables

Planning deliverable	No of respondents
Method statement	13
Cash flow Chart/ S Curve	11
Health and safety guidelines	7
Phasing plans	4
Design schedule	3
Information required schedule	6
Procurement programme	4
Site layout programme	7
Manpower loading graph	2
List of temporal works	1
Schedule on environmental issues	3
Area programme	4

7.3 Use of the baseline programme

In an attempt to find out whether contractors recognise the importance of baseline programme in resolving matters concerning projects DD, interviewees were asked to mention the uses to which programmes are often put. The following were mentioned by the respondents as the main uses:

A tool for planning, monitoring and control of the work (22.5%)

For assessing progress and identifying problem areas (20%)

Used for developing short-term rolling look–ahead programmes (15%)

For assessing the impact of variations and delays (15%)

As a tool for resolving delay and disruption claims (12.5%)

For coordinating the activities of project parties (10%)

Aids in the preparation of payment certificates (5%)

The results show that programmes are used for two main purposes as far as matters of projects DD are concerned: assessing the impact of delays and disruption (often in the

form of variations) during the course of the project and in claims arising out of this after project completion. The total percentage coming from these two was quite high suggesting that contractors are generally concerned with the use of programmes in resolving DD matters. Most interviewees mentioned that it is often not possible to resolve these matters in the course of the project as usually recommended as best practice (SCL, 2002; Kumaraswamy and Yogeswaran, 2003). A number of reasons were given as responsible for this; the most common was that complete assessment of impacts of DD events are often not possible to determine until sometime later or at the end of the project. They mentioned the consequence of this end of contract resolution of claims as disputes, which have to be resolved by third parties either in arbitration or other forms of dispute resolution mechanism depending on the contract. Most admitted that in all these stages; programmes are heavily relied on in resolving the claims as indicated in the flow chart below (Figure 7.1).

The appropriate use of the contract programme in this respect requires that the baseline programme be properly developed and managed. Since programmes not properly developed such as having wrong logics and lacking sufficient activities' details would not be considered as realistic baseline for DD analysis. In an attempt to assess how baseline programmes are currently developed, interviewees were first asked to comment on the experts involved in their development.

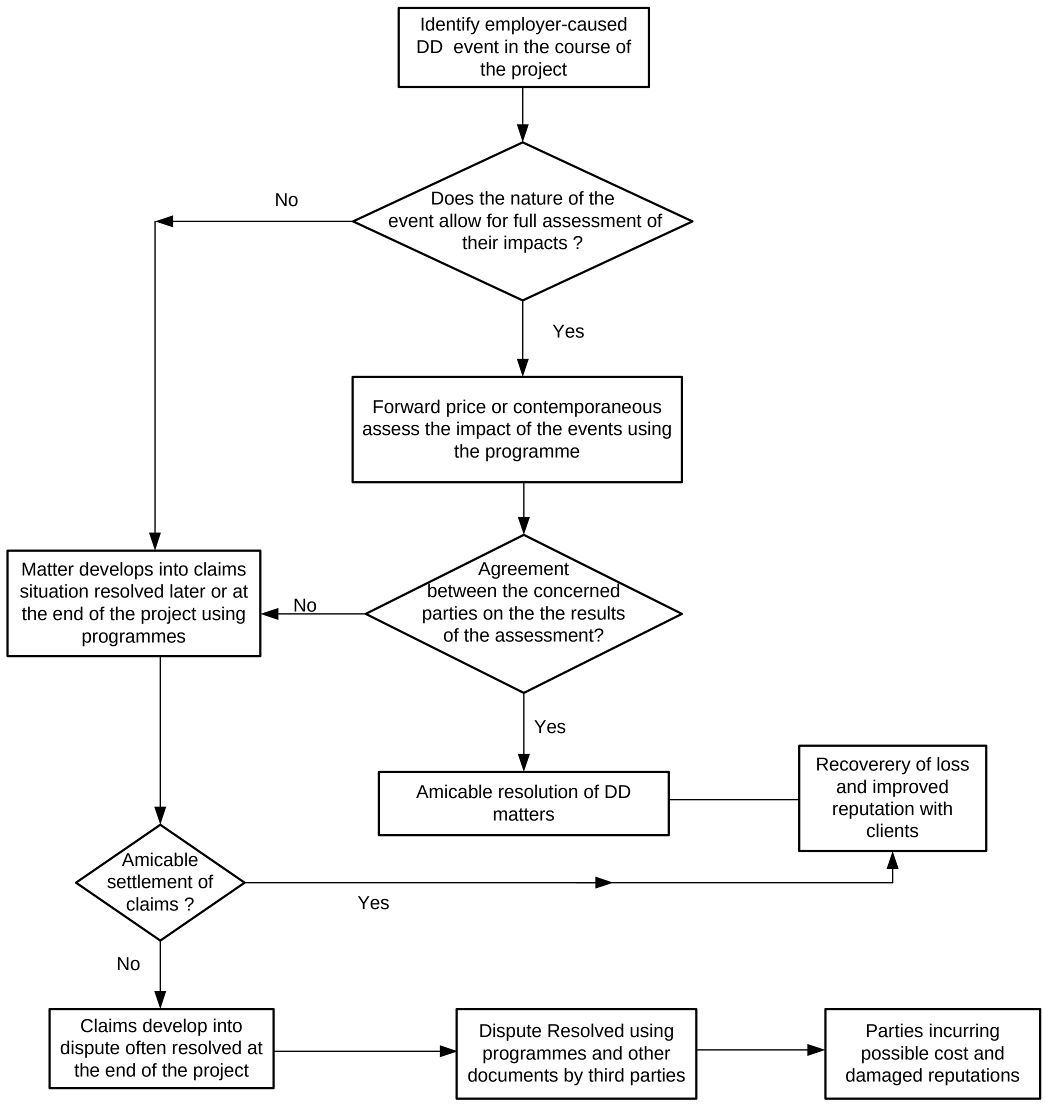

Figure 7.1 Use of programmes in delay and disruption management

7.4 Involvement in baseline programme development

Studies have shown that the development of reliable and useful construction programmes demands close cooperation between a number of personnel (Laufer and Tucker, 1988; Laufer *et al.*, 1993; Cohenca-Zall *et al.*, 1994). The type of experts involved in the development of programmes can therefore impact on the quality of the plans generated. Interviewees were thus asked to mention the relevant parties or staff who are often involved in the development of programmes. Their levels of

involvement were also assessed on a scale of 1-5 ("1 for lowest involvement" and "5 for highest involvement"). The results of the responses are indicated in Table 7.3.

Table 7.3 Involvement in preconstruction programming

Expertise	Level of involvement (in %)					Involvement index
	1	2	3	4	5	
Planning engineer	15.4	0.0	15.4	30.8	38.5	75.5
Project manager	23.1	15.4	38.5	15.4	7.7	53.9
Site manager/agent/engineer	30.8	38.5	23.1	7.7	0.0	41.6
Estimator	23.1	30.8	23.1	23.1	0.0	49.3
Contracts manager	46.2	15.4	30.8	7.7	0.0	40.0
Subcontractor/suppliers	38.5	38.5	30.8	0.0	0.0	41.6
Client/his agent	53.8	30.8	15.4	0.0	0.0	32.3

The result shows that the programming process involves many parties, most of which are internal to the construction company, with varying degrees of involvement. The different levels of involvement are understandable since the programming task is affected by a number of factors that are often in control by different parties (Laufer and Tucker, 1988; Laufer *et al.*, 1993). Planning Engineers and Project Managers appear to have more input than the other participating parties: Estimators, Subcontractors, Site engineer and the Client.

7.5 Resource loading and levelling

The basic assumption in developing a programme is that resources required by activities are unlimited. This assumption is, however, not valid as some resources are highly limited in most practical situations (Woodworth and Shanahan, 1988; Cooke and Williams, 1998). Thus, programming without considering resource limitations may result in unreliable programme as resource availability will affect the start time

of certain activities. It is also important to have resource loaded schedules because resource loading (Kuhn, 2007):

is critical to evaluating both network logic and task duration;

affects logic when too many tasks requiring the same craft or discipline are occurring at the same time; and

affects duration because addition or subtraction of resources will directly impact task completion time.

Therefore for a programme to serve as a realistic tool for DDA it requires that resources are allocated for each activity and scheduled in accordance with resource consumption limitations (labour, equipment, etc) by levelling or smoothing the resources. To assess the state of this in practice, respondents were asked to comment on the extent to which the programmes they produced are resource loaded and levelled, using a scale of 1-5 (1 for "never" and 5 for "always"). Table 7.4 shows the results.

Table 7.4 Extent of resource loading and levelling of programmes

Interviewee	**Resource loading**					**Resource levelling**				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
1		✓					✓			
2		✓				✓				
3	✓					✓				
4			✓					✓		
5	✓					✓				
6		✓						✓		
7	✓						✓			
8		✓				✓				
9	✓						✓			
10	✓					✓				
11		✓				✓				
12		✓					✓			
13	✓					✓				
14			✓					✓		
15		✓					✓			
%tage	40.0	46.7	13.3	0.0	0.0	46.7	33.3	20.0	0.0	0.0

The results show that over 80% of the respondents seldom resource-load their programmes. This is in reflection of the low rate of production of manpower loading graphs as indicted in Table 7.2. Only two interviewees claimed that they occasionally do carry out resource loading and that this is only done for some activities whose resource requirements can easily be determined. The rest gave reasons for not resource-loading their programmes as:

it is time consuming and difficult exercise to do;

following resource-loaded schedules in practice is difficult making it unhelpful;

it is impracticable for many activities as resource management is difficult;

it needs a lot of inputs from a lot of things making it a very complex thing to do;

it is often not part of clients' requirements.

As a result of this poor use of resource loading and levelling, it is likely that most programmes are not developed based on contractors' resources plan. This suggests that DD analysis based on such programmes could produce results not reflecting reality and thus may not be relied upon as basis for claims settlement. Reacting to this comment, some interviewee claimed that for potential claims events such as variation, they often resource-load its "fragnets" upfront before inserting it in the main programme in assessing their time and cost impacts prior to their execution. One respondent mentioned that in the absence of resource-loaded programmes, they sometimes create one retrospectively using actual records, although this can be a very laborious exercise to perform. When asked whether they do carry out resource levelling, over 80% answered that they seldom do it. Their reasons being that: (i) they do not see it as a critical consideration; (ii) not practical to do as resources are often difficult to control; and (iii) is a time-consuming task to undertake. The very few who

sometimes carry out resource levelling said they only do it for some works, particularly those in which one can easily move crew around. One interviewee commented: "*In practice, resources are often dedicated to a number of activities belonging to different work packages or are shared across several projects, making it inflexible to redistribute resources in order to smoothen or level them".*

The low rate of loading/levelling resources on programmes is an issue of concern in using these programmes for DDA. For instance, the selection between "retained logic" and "progress override" in CPM software packages is dictated by resource levelling carried out (Nosbisch and Winter, 2006). Adopting any of these logic mode in analysing a given claims problem gives different results (Arditi and Pattanakitchamroon, 2006) and thus may give rise to conflicts if the selection is done arbitrarily or based on what the analyst feels would give the results expected. Also using progress override in updating a schedule may depict an out-out-sequence progress, which may be challenged by the employer as problem areas of the contractor's programme if there is no reasonable basis for using this logic. Resource levelling is therefore employed to correct preferential logic in making the programme and its updates more reliable and transparent, thereby reducing disputes when applied in DD analysis (Nosbisch and Winter, 2006).

7.6 Programme updating

Interviewees were asked whether they do produce programme updates in the course of project and all answered in the affirmative. However, on the question of the interval at which they do carry out this, almost all the interviewees responded that it would depend on the nature of the project at hand, the terms of the contract and the

occurrence of major changes. Best practice, however, suggests that updating programme periodically at least on monthly basis is vital for the programme to continue to serve as a useful tool for managing and controlling the project (see Section 4.2). Interviewees were therefore asked to indicate how frequently they update programmes on monthly basis using a scale of 1-5 where “1=never” and “5=always”. As can be seen in Table 7.5, about 27% of the interviewees seldom prepare monthly programme updates, 33% sometimes do, 27% often do and 13% always do.

Table 7.5 Extent of programme updating and progress reporting

Interviewee	**Update programme monthly**					**Monthly progress reporting**				
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
1			✓						✓	
2				✓					✓	
3		✓								✓
4			✓					✓		
5				✓					✓	
6			✓							✓
7			✓						✓	
8				✓					✓	
9		✓						✓		
10		✓								✓
11			✓					✓		
12		✓							✓	
13					✓			✓		
14				✓				✓		
15					✓				✓	
%tage	0.0	26.7	33.3	26.7	13.3	0.0	0.0	33.3	46.7	20.0

They were also asked to describe briefly how they do the updating. All the respondents mentioned that they usually update their programmes in terms of time and duration requirements of activities but not in terms of quantities of work completed. The following sums up the views expressed by the respondents:

(i) Nine (9) interviewees said progress data in terms of actual logic, start and finish dates of activities completed and the remaining durations for activities started

but not yet completed as at the update date are plug into the previous updated programme.

(ii) The rest mentioned that in addition to doing the above, they also attempt to reprogramme the remaining work particularly when the update shows that the project is behind schedule in order to bring the project back on track.

Finally on updating, interviewees were asked to mention the expertise or parties that are usually involved in the updating and their respective degree of involvement using a scale of 1-5 where "1 is for lowest involvement" and "5 for highest involvement". Five main experts were mentioned with different levels of involvement as shown in Table 7.6.

Table 7.6 Involvement in programme updating

Expertise	**Level of involvement (in %)**					**Involvement index**
	1	**2**	**3**	**4**	**5**	
Planning engineer	7.7	38.5	23.1	15.4	15.4	58.5
Project manager	30.8	30.8	23.1	15.4	0	44.7
Site manager/agent/engineer	7.7	15.4	23.1	30.8	23.1	69.3
Quantity surveyor	38.5	30.8	15.4	15.4	0.0	41.6
Subcontractor/suppliers	46.2	38.5	15.4	0.0	0.0	33.9

As expected, site manager/agent/engineer has the highest level of involvement because of their constant touch with the day-to-day execution of the programme. This role provides them with all the necessary information on progress needed for updating. One interviewee commented: *"We train our site agent on how to update the programme. The planner only comes on board during updating on site or in claims situations when they are in problem situations or it is difficult for them."*

A remarkable observation was that none of the interviewees mentioned any involvement of the employer or its representative in updating. This is an issue of concern because without the involvement of the contract administrator, an updated programme produced may not be regarded credible. Also, their lack of involvement may result in inadequate records on their side with regard to what actually took place during the construction process. This can affect their ability to perform contractor's DD claims assessment contemporaneously or after the fact, although the contractor may have to provide the necessary information.

7.7 Progress reporting

Interviewees were asked to indicate the extent to which progress is reported monthly to the employer, using a scale of 1 to 5 ("1 for never" and "5 for always"). The results are as shown in Table 7.5, which indicates that majority (over 60%) usually produce monthly progress. In attempt to understand what they usually report on, interviewees were asked to give an overview of the usual content of their progress report. The following summarises their responses:

Health and safety performance (100%)

Financial status- payments due, certificates submitted, claims, etc (92.3%)

Update on design- design information, drawings, etc received and those outstanding (92.3%)

Progress update – percentage complete of baseline activities, activities that are delay and why, state of variations, when the job is likely to finish, etc (92.3%)

Procurement issues- materials, equipment, subcontractors, etc procured or yet to procure (84.6%)

Statutory and other approvals on issues concerning planning, utilities, the public and the environment (77%)

Resources on site – number and state of various plants/equipment on site (61.5%)

Quality control checks (53.8%)

Although the above are all relevant sources of information for DD analysis, not all the respondents do report progress on all of them except for Health and Safety. This can affect the quality and availability of contractors' as-built records and thus make it difficult to analyse DD properly using reliable methodologies. Such methodologies require adequate and accurate project documentation for performing detailed analysis such as:

verifying the accuracy of CPM dates reflected in the baseline programme, its updates and the as-built programme;

identify and correlate events that may have occurred in respect of the activities for establishing any shift in the programme;

developing a correlation between as-planned activities and milestones with their as-built counterparts to identify any variances responsible for the project delay;

identifying the start and finish date of relevant activities;

identification of float values of activities in programme updates;

identification of as-planned critical path, as built critical path and changes in critical paths in various updates;

checking for activity relationships in the as planned programme, its updates and the as-built programme for accuracy and reasonableness;

investigating and documenting productivity and cost impacts of activities causing delays; and

investigating any variances of the programme due to disruption events.

7.8 Keeping records of crew productivity

Interviewees were asked to indicate on a scale of 1-5 (where "1=never" and "5= always") the extent to which they keep records of crew productivity for each of the activities on the contractor's programme. As shown in Table 7.7, only 13% indicated that they sometimes keep such records, while the remaining 87% seldom or never do. The very few who sometime keep such records mentioned that they do so only when executing variations or compensation events that do not have equivalent bill item. In other words, they do not keep productivity records of activities as part of their normal duties except when executing claim-leading events like extra works or changes. One contractor stated: *"Daily documentation of productivities achieved for major activities is an onerous task and will only be useful when loss productivity claims are to be filed. Such claims are not often pursued by our company so we only keep detail productivity records when executing activities that are likely to be subject of claims".*

When asked to give the reasons why such records are not kept routinely for major activities, 8 of the interviewee who responded gave the following reasons:

high resources are involved in keeping such records (100%)

staff often regard such record keeping as waste of time and resources as they do not often make use of them (75%).

the productivity figures given in estimating books (particularly for civil engineering works), are often no where near the actual site productivity values (50%)

The nature of most activities makes it difficult to track or keep productivity records (75%)

Table 7.7 Extent of keeping crew productivity records

Interviewee	Keeping productivity records				
	1	**2**	**3**	**4**	**5**
1	✓				
2	✓				
3		✓			
4			✓		
5		✓			
6	✓				
7		✓			
8	✓				
9	✓				
10		✓			
11			✓		
12		✓			
13	✓				
14		✓			
15	✓				
Percentage (%)	46.7	40.0	13.3	0	0

The major reason given was high expense involved in keeping such records. Even though this is a genuine reason as it is burdensome to job-site personnel, claimants risk having their claims reduced or, even worst, dismissed completely if they fail to provide adequate documentary evidence to support their claims (Kangari, 1994). Not only does the keeping of adequate records ensures that contractors are prepared when claims and subsequent disputes do arise, it can also avoid claims arising in the first place. It is important therefore for contractor's to weigh the time and cost involved in keeping such records against proper and legitimate claims failing entirely, or in part, because of lack of documentary evidence.

7.9 Summary

This chapter reports the results of interviews undertook to understand the underlying causes of programming problems that affect the use of DD analysis methodologies. The issues investigated include: development of the baseline programme-involvement, format and software used and considerations of resource loading; the management of this programme, productivity records keeping and progress reporting. The main findings are as follows:

(a) Most contractors prefer to use the linked bar chart format for their contract programme which has logic difficulties when used for projects with complex sequencing of activities.

(b) Computers are used to produce the programmes with the most popular software for this being *CS Project* and *Power Project*, followed by *MS Project*, with Asta *Teamplan* as the least popular. These packages have inadequate functionalities as far as their use for DDA is concerned, except for simple cases.

(c) In addition to the contract programme, other planning deliverables produce during precontract stage are: method statement, cash flow chart/S-curve, health and safety guidelines, phasing plans, design schedule, information required schedule, procurement programme, site layout programme, manpower loading graph, list of temporal works, schedule on environmental issues and area programme.

(d) The most important use made by contractors of contract programmes during construction were as a control tool and a tool for assessing progress, impact of variations and delays and for identifying problems areas.

(e) The development of baseline programme involves many different expertise most of which are staff of construction firms. The Planning Engineer/Planning Manager appeared to have the highest input, whilst the client/his agent makes the lowest input.

(f) Most of the programmes produced are not resource loaded and levelled. This has a deleterious effect in the use of the programmes for proving or refuting delay claims.

(g) Most contractors update their programmes monthly. This process requires the input of a number of experts; with the highest input coming from Site Manager/Agent/ Engineer and lowest from Subcontractors/Suppliers. There is no involvement of the client or his representative and this can affect their ability to properly assess DD claims using accurate methods.

(h) Monthly progress report is often submitted to the employer by contractors. However, some contractors do not report on all the relevant matters that contain relevant information for undertaking DDA. This is likely to create difficulties in the use of more detailed DDA methodologies.

(i) Records of crew productivity for major activities are not kept on regular basis as a routine. A number of reasons were cited as responsible for this; the main one being high expense involved in keeping the records.

CHAPTER EIGHT

8 A BEST PRACTICE MODEL FOR SELECTING APPROPRIATE DAM

8.1 Introduction

The findings reported in Chapters 3 and 5, in respect of use of existing DAMs, suggest that there is no industry-wide agreement on which methodology should be employed in delay claims. Unfortunately, most forms of contract seldom specify the method that should be used to perform the analysis, either in the course of the project or after. Such specification has become very important given the myriad acceptable DAMs that are available for use.

Claim parties and their delay analysts therefore usually adopt their own DAM for proving or disproving the claims based on their own accumulated experience, expertise and intuition (Kumaraswamy and Yogeswaran, 2003; SCL, 2006). This has been a recipe for disputes mainly because the various DAMs produce different results when applied to a given claims situation as highlighted in Section 5.3.3. The only solution offered for this problem has been the recommendation that the best methodology for any situation should be selected based on a number of criteria (Bubshait and Cunningham, 1998; SCL, 2002). However, apart from the fact that the criteria vary from analyst to analyst, they are qualitative, subjective and imprecise in nature, making their use in methodology selection open to challenge. There are also no standard guidelines or approach (perhaps a decision tool) that can assist analysts in this to ensure a more objective selection process.

Inspired by the need to address this problem, a model for the selection of an appropriate DAM has been developed. This is intended to serve as a tool for assisting analysts in justifying their choice of DAM to their clients and/or the trier-of-fact when the contract is silent on the method to use. Claim parties can also rely on it to arrive at balanced rather than partisan results if they have to come to an agreement on which DAM should be used for analysing the claims. This chapter reports on the development of the model and is organised as follows: (i) brief notes on the need for a decision model for the selection of DAM (ii) an overview of existing decision-making models (iii) selecting the model adopted for this study (iv) developing the DAM selection model (v) capabilities and limitations of the model.

8.2 The need for decision model for DAM selection

Like in any other discipline; employers, contractors and other stakeholders of construction projects must make numerous decisions right from the inception of a project, majority of which will influence the project's profitability. One of such decision is the task of identifying appropriate DAM prior to using it to prepare or assess delay claims either in the course of the project or after. This has become a major problem for analysts as highlighted in the previous section. A major cause of the problem is the fact the criteria by which the selection of the right methodology is to be based are many and conflicts with each other. For instance, most analysts will agree that methodologies that are simple and inexpensive to operate will always be preferred over complex and expensive methods if DD claims are all the time simple. In this case, it will be easy to predict, for instance, that a methodology which is less costly, simple and easy to apply such as as-planned vr as-built will always be preferred over time impact analysis which is relatively costly and difficulty to use (all

other things equal). However, it will be a different matter if the nature of the claims situation were to be described as very complex with significant money involved, which is typical of modern construction and engineering projects claims. In this case, a methodology which is more comprehensive and capable of dealing with the claims complexity such as the Time Impact Analysis or Window Analysis will be more appropriate to use.

Moreover, real life claims situations are affected by many more factors than those considered in the above scenarios. There are also many more methodologies with no single methodology having attributes better than the best offered by other methodologies (Arditi and Pattanakitchamroon, 2006). For these reasons, the question of which of the methodologies is best to use is difficult in practice, often attracting the response “it depends” (Harris and Scott, 2001). This decision to select the best methodology thus cannot be resolved using simple decision rules. It rather requires the use of a decision model which will enable analysts to trade-off the available selection factors against the various DAM.

8.3 Overview of Decision Models

Dixon (1966) described “decision-making” as the process of making a “correct” decision by choosing the one alternative from among those that are available which best balances or optimises the total value, considering all the various factors. This require the decision maker weighing value judgements that involve economic factors, technical practicabilities, scientific necessities, human and social considerations, etc. (Dixon, 1966). This is particularly difficult to make because of limited human rationality and the information processing demand of many problem situations (Holt

et al., 1994). To overcome this difficulty, a family of tools often referred to as "Multi-Criteria Decision-Making (MCDM) methods" have evolved over the years as aids for decision-making.

MCDM tools vary from simple approaches to quite sophisticated methods in commensuration with the varying levels of problem intricacy. They also range from qualitative to quantitative in their treatment of available data relevant in decision-making (Russell, 1992). The tools include: Scoring Multi-Attribute Analysis (SMAA), Multi-Attribute Utility Theory (MAUT), Multivariate Discriminate Analysis (MDA), Linear Programming, Decision Tree Analysis, Multiple Regression, Fuzzy Set Theory (FST), Cluster Analysis (CA), Analytical Hierarchy Process (AHP) and Knowledge-based Expert Systems (KBES) (see for instance, Keeney and Raiffa (1976), Yoon and Hwang (1995); Russell (1992) and Holt (1998)). The field of resolving decision problems using MCDM tools has advanced significantly in the last two decades (Shim *et al*., 2002). The tools have been used in a wide variety of applications domain where decision makers have to deal with complex, unstructured and difficult decision task. Examples of such applications include: the analysis of construction decision problems using SMAA, MAUT, KBES, AHP, and FST (Amirkhanian and Baker, 1992; Paek *et al*., 1992; Russell, 1992; Holt *et al*., 1994; Chinyio *et al.* 1998; Wong and Holt, 2003; Ling, 2003; Mahdi and Alreshaid, 2005); and the analysis of environmental and energy issues (Lootsma, *et al.,* 1986; Bell *et al.*, 2003; Greening and Bernow, 2004), just to mention a few.

The common aim of all MCDM tools is to provide a rational framework for making decision in the presence of multiple, usually conflicting, criteria. The characteristics common to most MCDM problems include (Keeney and Raiffa, 1976):

finite numbers of alternatives, which can be screened, prioritise, selected, and/or ranked;

numbers of attributes which depend on the nature of the problem;

set of units specific to the measurement of each attribute;

potential for characterisation of the alternatives relative of each attribute, usually through an ordinal or cardinal scale; and

a matrix format where columns indicate attributes considered in a given problem and rows list competing policy alternatives.

These characteristics are typical of DAM selection. Therefore the most suitable decision tool to use for this model is one of MCDM.

MCDM problems are commonly categorised as discrete or continuous, depending on the domain of decision alternatives (Yoon and Hwang, 1995). Discrete for where there is well-defined, usually limited, number of predetermined alternatives, requiring inter and intra attribute comparison, involving implicit or explicit tradeoffs. On the other hand, continuous is for where decision variables are to be determined in a continuous or integer domain, of infinite or large number of choices, to best satisfy the decision-making constraints, preferences or priorities. The approaches for evaluating these problems are respectively classified as multi-attribute analysis (MAA) and multiple-objective analysis (MOA). The latter is commonly used for design problems as these are often concerned with the selection of the best option from amongst a potentially infinite set of options that satisfy a set of constraints. Such approach is therefore unsuitable for the multi-criteria nature of DAM selection problem which has finite alternatives.

The tool adopted for the DAM selection model was carefully selected to ensure an optimum or "best" possible solution to the decision problem at hand. To appreciate the appropriateness of the selected tool, a succinct description of the more popular tools is provided below. Detail description of the tools is not within the scope of this chapter; literature abounds for thorough investigation of this subject where necessary.

8.3.1 Scoring Multi-Attribute Analysis (SMAA)

This is a technique for evaluating multi-criteria decision problems to identify the best decision alternative from several well-defined alternatives (Finlay, 1994). Anderson *et al.* (2005) have spelt out the analysis involved in this technique in clear steps as follows:

Step1. Develop a list of the criteria to be considered. The criteria are the factors that the decision maker (DM) considers relevant for evaluating each decision alternative.

Step 2. Assign a weight to each criteria that describes the criterion's relative importance. Let w_i = the weight of criterion *i*.

Step3. Assign a rating for each criterion that shows how well each decision alternative satisfies the criterion. Let r_{ij} = the rating for criterion *i* and decision alternative *j*.

Step 4. Compute the score for each decision alternative as follows:

$S_j = \sum w_i r_{ij}$; where S_j is the score for decision alternative j

Step 5. Order the decision alternatives from the highest score to the lowest score to provide the scoring model's ranking of the decision alternatives. The decision alternatives with the highest score is the recommended decision alternative.

The simplest form of SMAA is expressed as $S_j = \sum r_{ij}$ (i.e. without any weightings (W_i)) and is termed simple scoring MAA (Holt, 1998). This has major weakness as r_{ij} is often a very subjective measure. The purpose of the weighting indices is to heighten the aggregated scores of the various alternatives in commensuration of their satisfaction in relation to the various criteria. The W_i may be a function of (Holt, 1998): sole practitioner experience/predilection; group consensus opinion and survey and analysis of data, from a sample pertinent to the selection setting in which the model will be applied.

8.3.2 Multi-attribute utility theory (MAUT)

This technique is similar to SMAA except that it uses "utility" to quantify the subjective components of the attributes. The term "utility" is used to refer to the measure of desirability or satisfaction of an attribute of the alternative under consideration. It gives an abstract equivalent of the attribute being considered from natural units such as years, or £ into a series of commensurable units (utiles) on an interval scale of zero to 1 (Holt, 1998). As in SMAA, utility values can be used in conjunction with weightings, W_i, to give a more reliable aggregate score for the various alternatives. MAUT is expressed mathematically as:

$S_j = \sum_{i=1}^{n} W_i U_{ij}$ *;* Where U_i represents the abstract equivalent expressed in utiles for the *i*th attribute of the *j*th alternative and n is the attributes considered by the decision maker.

8.3.3 Multiple Regression (MR)

This is a statistical technique used to develop a model for observing and predicting the effect of a number of independent variables upon a dependent variable. In general, a MR model for predicting an outcome *Y*, a function of independent variables, $X_1, X_2, \ldots X_n$ is given by equation of the form:

$$Y = a + b_1(X_1) + b_2(X_2) + \ldots + b_n(X_n)$$

Where *a* is the constant representing the y-axis intercept of the regression line; $b_1, b_2, \ldots b_n$ are the partial regression coefficients representing the amount the dependent variable *Y* changes when the corresponding independent variable changes 1 unit and *n* is the number of independent variables.

In applying MR as a decision-making technique, the various attributes or criteria will be represented as independent variables and the dependent variable will represent the total score obtained by each alternative.

Associated with multiple regression is R^2, *coefficient of determination*, representing the percent of variance in the dependent variable explained collectively by all of the independent variables. The higher it is, then the more accurate the model is able to predict. The difference between the actual values of *Y* and those predicted by the model is known as residuals.

8.3.4 Linear programming (LP)

LP is an optimising tool for identifying maximum or minimum value of a linear function, $f(x_1, x_2, \ldots . x_n)$ called an objective function, subject to a number of linear constraints of the form $Ax + By + Cz + \ldots \leq N$ or $Ax + By + Cz + \ldots \geq N$. LP is thus a MOA technique.

The largest or smallest value of the objective function is called the optimal value, and a collection of values of $x, y, z, \ldots$ that gives the optimal value constitutes an optimal solution. The variables $x, y, z, \ldots$ are called the decision variables.

8.3.5 Cluster analysis (CA)

Cluster analysis is a tool for grouping objects (people, things, events, etc) of similar kind into respective categories. By this, any associations and structure in a data, which hitherto were not evident, may be discovered. It has thus been a very useful too for developing taxonomies or classification system. There are three main types of CA: *Joining (Tree Clustering)*, *Two-way Joining (Block Clustering)*, and *k-Means Clustering.*

Although CA is generally meant for solving classification problems, it has been used widely as a decision tool (Holt, 1998). In this application, a classification algorithm is first used to group the given number of alternatives into a number of clusters such that alternatives within classes are alike and unlike those from other clusters. This reduces the original set of alternatives into manageable sub-sets of like characters. These sub sets are then analysed considering their attributes to identify the best alternatives.

8.3.6 Multivariate discriminant analysis (MDA)

MDA is also a statistical analysis technique concerned with separating distinct set of objects (or observations) based upon their observed independent variables (Klecka, 1980). The technique begins by finding the most discriminating variable, which is then combined with each of the other variables in turn until the next variable is found which contributes most to any further discrimination between the groups. The process continues in a similar manner until such time as very little discrimination is gained by inclusion of any further variable (Holt, 1998).

The criteria which best discriminate between groups and which are most similar is confirmed by computing the ratio of between-group variation to within-group variation, simultaneously for all the independent variables (Klecka, 1980). The discriminate factors are then used to develop a linear discriminate function of the form:

$$Z = C_0 + C_1V_1 + C_2V_2 + \text{........}C_nV_n$$

Where Z is the score of the discriminant function; V_n is the nth discriminating variable; C_n is coefficient of V_n and C_0 is a constant.

8.3.7 The technique adopted for the DAM selection model

Even though there are several decision analysis tools available for use, the key question is which of these should be adopted for the DAM selection model, which can be seen as a MCDM problem on its own. The choice of the appropriate tool is a function of the nature of the decision problem and the kinds of information deemed relevant to the decision makers (Keeney and Raiffa, 1976; Yoon and Hwang, 1995). Table 8.1 gives a summary of the various tools based on the levels of information on

the decision-making environment and the nature of output results as described by Holt (1998) and Greening and Bernow (2004).

Table 8.1. Characteristics of decision-making tools (Holt, 1998; Greening and Bernow, 2004)

Technique	Nature of input data	Nature of output
Scoring multiattribute analysis	Interval and ordinal but subjective	Numeric score and ranks and hence rank amongst alternatives
Multi-attribute utility theory	Raw data is often qualitative, utility achieves interval data	Numeric score and ranks and hence rank amongst alternatives
Multiple regression	Interval predictive	Numeric; further value
Linear programming	Value judgement on the importance of an over-all objective	Maximisation of objective function
Cluster analysis	Multivariate	Group membership/group characteristics
Multivariate discriminant analysis	Multivariate	Group membership/group characteristics

In the light of the above characteristics and the functions of the various tools as described in the previous section, the tool that appears most suitable for the DAM selection model will be one of Multi-attribute analysis methods (MAA- either SMAA or MAUT). Figure 8.1 shows a conceptual framework of how a MAA tool can aid in the selection of a DAM.

The wide application of MAA tools in one form or the other by a number of researchers in the construction industry is an indication that these tools are particularly suitable for construction decision problems. Examples of such applications include the use of SMAA for the analysis of design/build contractor

evaluation (Janssens, 1992) and the selection of architects (Ling, 2003); the use of MAUT for the selection of an item of plant (Harris and McCaffer, 1991) and the selection of contractors (Moselhi and Martinnelli, 1981; Diekmann; 1981; Russell and Skibniewski, 1988; Russell, 1992; Holt, 1998).

On the basis that MAUT requires the use of utility function technique to determine abstract values for each DAM attributes which the current study do not have, SMAA was elected as the most suitable tool for the DAM selection model. The survey of DD analysis professionals, which determined *inter alia*, attributes weightings in the form of importance indices (see Chapter 6) make the use of SMAA more suitable than MAUT. Moreover, SMAA is a well defined and easily understood tool, especially with regard to the applications of the attributes and selection criteria. This quality is one of the hallmarks of a good decision tool (Greening and Bernow, 2004).

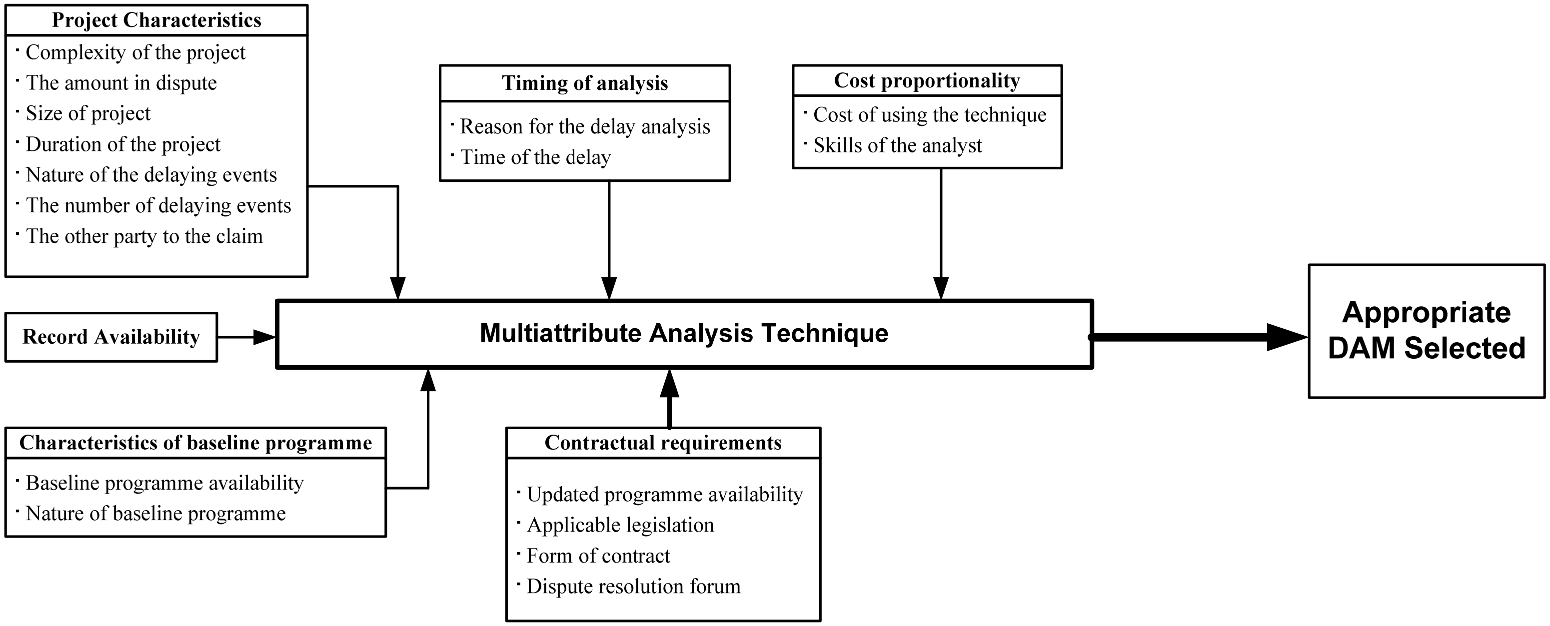

Figure 8.1 Conceptual Framework for the selection of DAM

8.4 Construction of DAM selection model

According to Kepner and Tregoe (1975), there are seven factors that are essential in decision making. These factors, in their order of consideration, are: establish the overall objectives which are essential or desirable; classify the objectives according to importance; establish alternatives choices; evaluate the outcome for each alternative; choose the best alternative as the preliminary decision; re-evaluate the decision and assess the adverse possibilities of that choice and finally, set up contingency plans to control the effects of the final decisions. Tuning this framework to the problem of DAM selection coupled with the procedure set out for SMAA, Figure 8.2 is proposed as the flow chart describing the procedure involved in developing the model. The following section provides detail description of the main steps contained in the procedure.

8.4.1 Identification of DAMs and selection criteria

This requirement was achieved via literature review on DAMs (Chapter 5) and the survey of the use of the methods in practice (Chapter 6). These chapters highlight the existing methodologies for analysing delays and the relative importance of the criteria for selecting the appropriate one for any given claims circumstances. The most commented upon DAMs are As-planned vrs as-built, Impacted as-planned, Collapsed as-built and the Time impact analysis/Window analysis. The model was therefore designed for selecting a methodology from among these. The generic selection factors (or criteria) are: Project characteristics, Contractual requirements, Characteristics of baseline programme, Cost proportionality, Timing of the analysis and Record availability.

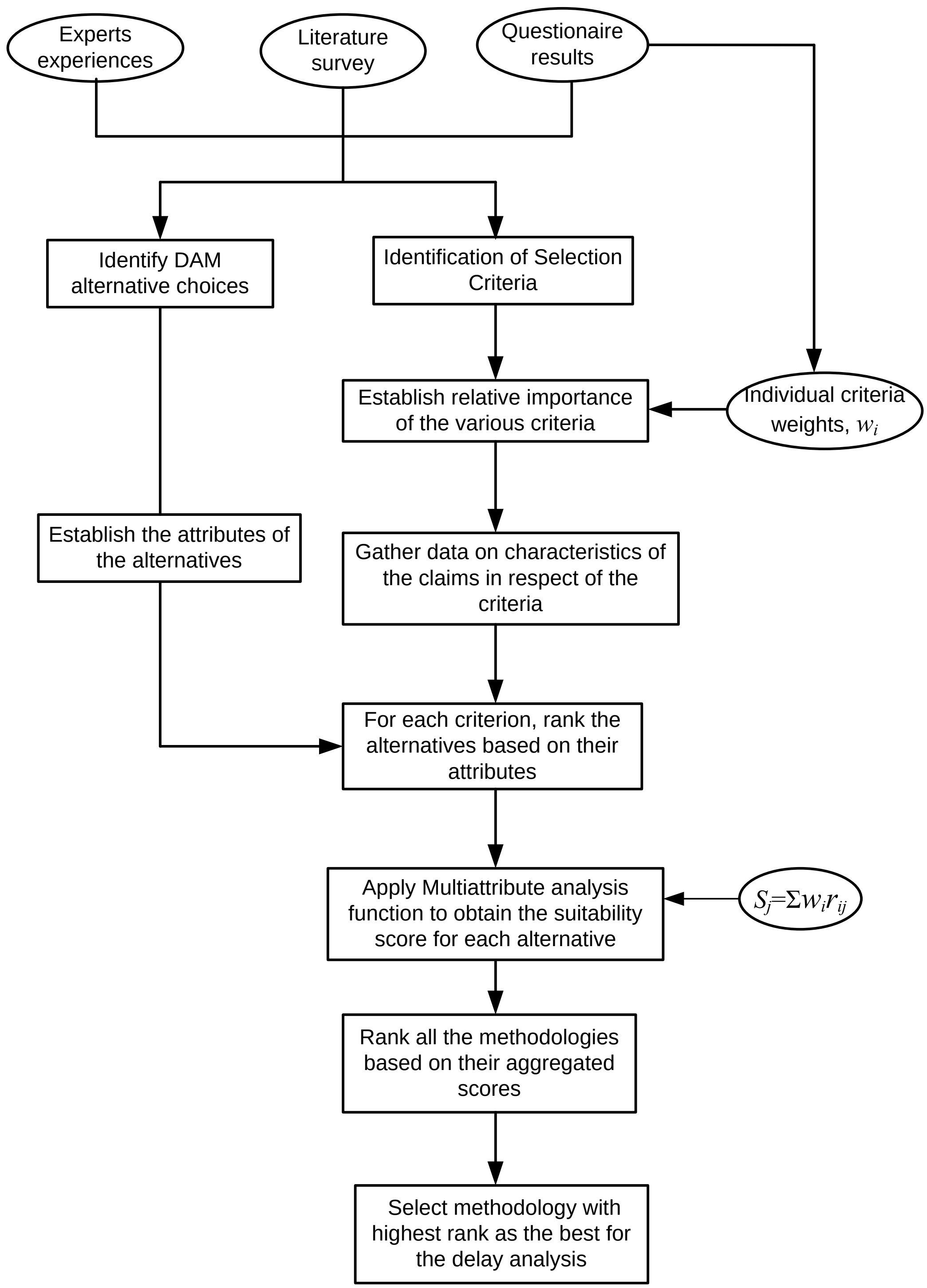

Figure 8.2 Model for the selection of DAM

8.4.2 Gathering data on selection criteria

To be able to rank the competing methodologies against the various selection criteria, data in respect of these criteria will have to be gathered and analysed. The sources of this data are the claims itself, the contract document, project as-built records and other project documentations.

8.4.3 Rating of DAMs in respect of the selection criteria.

This step involves rating the suitability of the various methodologies successively against each criterion in reflection of the extent to which the method is suitable to use given the criterion under consideration, using a scale of 0-1; "1 for very suitable" and "0 for not suitable". The various methodologies have different attributes which have to be determined against the selection criteria to facilitate their rating. Some of the criteria have sub-criteria that can be attributed to them so to assign rates to such criteria; each sub-criteria would have to be considered and assigned a rank. For such criteria, the score can be calculated mathematically as:

$$SCX_j = scx_{1j} + scx_{2j} + \dots scx_{nj}$$

Where SCX_j = criteria score for methodology j;

$scx_{1j\dots\dots nj}$ = sub-criteria scores attributable to criteria X for methodology j. These are equally weighted with the constrain that $\sum scx_{nj} \leq 1$.

The problem, however, with the rating here is the fact that some of the criteria are intangible and also have different units of measurement making it difficult to evaluate them. Therefore to facilitate the rating process, the means or approaches by which each of the selection criteria could be evaluated has been presented in Section 8.4.6.

8.4.4 Computing suitability scores for the methodologies

Having rated the methodologies against each of the selection criteria, the next stage is to compute their respective total suitability scores using the equation: $S_j = \sum w_i r_{ij}$; where the terms have their usual meanings as defined before. These scores can be obtained easily by tabulating the individual scores for each criterion as indicated in Table 8.2. The fourth column of this table shows the weights (w_i) of the various criteria as calculated by normalising importance ratings responses obtained from the questionnaire survey. Column 5 shows their respective ratings. The total suitability score for each methodology is obtained by summing up all the entries in Column 6.

8.4.5 Selecting the most appropriate methodology

Following the computation of the total suitability scores for each DAM, the next step, which is the last, is to rank the various methodologies based on their total scores. The methodology with the highest score and ranks highest should thus be selected as the most appropriate methodology for the delay analysis.

Table 8.2 Computation of suitability scores of DAM

Group Factor	Selection Factor	Rank index	Weight	Rating	Score
Record availability	Record availability	97.5	1.0	Rd_1	$1.0xRd_1$
Baseline programme characteristics	Baseline programme availability	84.1	0.86	Rb_1	$0.86xRb_1$
	Nature of Baseline programme	71.5	0.73	Rb_2	$0.73xRb_2$
Contractual Requirements	Updated programmes availability	69.8	0.72	Rc_1	$0.72xRc_1$
	Applicable legislation	36.5	0.37	Rc_2	$0.37xRc_2$
	form of contract	59.2	0.61	Rc_3	$0.61xRc_3$
	Dispute resolution forum	54.4	0.56	Rc_4	$0.56xRc_4$
Timing of the analysis	Reason for the analysis	61.8	0.63	Rt_1	$0.63xRt_1$
	Time of the delay	62.0	0.64	Rt_2	$0.64xRt_2$
Project characteristics	Project complexity	65.8	0.67	Rp_1	$0.67xRp_1$
	The amount in dispute	73.1	0.75	Rp_2	$0.75xRp_2$
	Size of the project	50.9	0.52	Rp_3	$0.52xRp_3$
	Duration of the project	45.1	0.47	Rp_4	$0.47xRp_4$
	Nature of delaying events	64.6	0.66	Rp_5	$0.66xRp_5$
	Number of delaying events	66.1	0.68	Rp_6	$0.68xRp_6$
	The other party to the claim.	44.7	0.46	Rp_7	$0.46xRp_7$
Cost Proportionality	Cost of using method	58.0	0.59	Rs_1	$0.59xRs_1$
	Skills of the analyst	65.3	0.67	Rs_2	$0.67xRs_2$
				Total score	$S_j = \sum w_i r_{ij}$

8.4.6 Evaluating the various selection criteria against the methodologies

To rate the four methodologies against the selection criteria as described in stage (iii) above (Section 8.4.3), the attributes of each of the methodologies have to be compared with these criteria in turn. The different attributes of the various methodologies as reported in the literature have been gleaned and presented in Tables 8.3-8.9 and Figure 8.3, and set out under the various criteria below. A number of questions are then asked with regards to the extent to which a given methodology is suitable for use based on these attribute and the criterion in question. In addition to the

attributes, the following defines the questions for each criteria that will facilitate rating of the methodologies.

Records availability

Table 8.3 shows the type of project information required for the use of the various DAMs. To rate a methodology, the question to ask is: *Is there enough project information for the use of this methodology?* Using Table 8.3 as a guide, the percentage of information available for the proper use of the methodology is calculated to represent the methodology's suitability rating on this criterion.

Table 8.3 Important project information required for the application of DAMs

Record	**As Planned vrs As Built**	**Impacted As Planned**	**Collapsed As Built**	**Window analysis**
Outline of delay events	✓	✓	✓	✓
Start dates of delay events	✓	✓	✓	✓
Finish dates of delay events	✓	✓	✓	✓
Activities affected by delays			✓	✓
Duration of delay events	✓	✓	✓	✓
Original Planned completion date (or as extended)	✓	✓		✓
Actual completion date	✓		✓	✓
As-Planned critical path(s)	✓	✓		✓
As-built critical path	✓		✓	
Updates critical or near critical path(s)				✓
Update or Schedule revision dates				✓
Activity list with logic and lag	✓	✓	✓	✓

Baseline programme availability

Some methodologies require baseline programme for their implementation while others do not (see Table 8.4). The question here is: *Is there a baseline programme?* If **Yes**, score "1" for methodologies that need this programme for implementation. If **No**, score "0" for such methodologies.

Nature of baseline programme

It is not enough for a baseline programme to be just available; the programme would have to be reliable in terms its completeness (i.e. showing all project activities), activity durations, details and relationships. These sub-criteria are defined in Table 8.4 below. The question to ask in rating a methodology is: *Does the baseline programme satisfy all these sub-criteria?* A methodology is then rated by calculating the percentage of sub-criteria that are adequately catered for by the baseline programme.

Table 8.4 Main programming requirements of DAMs

	As Planned vrs As Built	**Impacted As Planned**	**Collapsed As Built**	**Window analysis**
Baseline programme available	✓	✓		✓
Nature of Baseline programme				
Available in CPM	✓	✓		✓
Includes all relevant activities	✓	✓		✓
Reasonable activity durations	✓	✓		✓
Reasonable activity relationships	✓	✓		✓
Activities defined in appropriate detail	✓	✓		✓

Updated programme availability

Table 8.5 outlines important programmes updates required by the various DAMs. The question here is: *Are these programme updates available?* A methodology is then rated as the percentage of updates that are availability for its use.

Table 8.5 Relevant programmes updates for DAMs application

Updated programmes availability	**As Planned vrs As Built**	**Impacted As Planned**	**Collapsed As Built**	**Window analysis**
Intermediate regular programme updates available				✓
Final updated programme available (as-built programme)	✓		✓	✓

Applicable legislation

The contract may be governed by certain legal procedures or rules which are required to be followed by the disputing parties when resolving disputes. This can constrain the methodology to be used. So in rating a methodology, the question is: *Is the use of the method affected by certain legal procedures or rules which ought to be followed in the claims settlement process?* If **Yes**, rate the methodology 0.0, otherwise rate it 1.0.

Form of contract

Unlike the USA, most of the contracts used in the UK are silent on the methodology to be used for analysing delays. However, certain contractual provisions may constrain the methodology to adopt; typical of which are provisions regarding relief (in the form of time extensions) from liquidated damages for employer risk events. The question here is thus: *What are the terms of contract in relation to entitlement to extensions of time as a result of delay events that are at the employer's risk?* On this, most forms of contract in the UK can be classified into two:

(a) Contracts that provide that the contractor is only entitled to time extension for delays that actually cause delay to completion and

(b) Contracts that provide that the contractor is only entitled to time extension for the likely effect of the delays.

Retrospective DAMs are suitable for case (a) and so should be rated 1.0 if the contract stipulates so and 0.0 for prospective methods. Opposite rating should be accorded in case (b).

Dispute resolution forum

Over the years DD claims have been settled in negotiation, mediation, adjudication, arbitration or litigation. The Analysts experience with these forums will give some

information as to the extent of acceptability or reliability of various DAMs in their use in these forums. So the question to ask is: *Is the methodology in the "good books" of the forum likely to settle the disputes?* If **Yes** or not known, rate it 1.0, otherwise rate it 0.0.

<u>The reason for the delay analysis</u>

Table 8.6 shows the capabilities of the methodologies in proving important delay claims issues. The question that will facilitate rating here is: *What are the issues of entitlement to be proved in the dispute?* Using Table 8.6 as a guide, a methodology is rated as the percentage of claims issues that it is capable of proving. For example a rate of 1.0 should be accorded if it is capable of proving all these issues.

Table 8.6 Capabilities of DAMs in proving common delay claims issues

Claims issue	**As Planned vrs As Built**	**Impacted As Planned**	**Collapsed As Built**	**Window analysis**
Extension of time	✓	✓	✓	✓
Prolongation cost	✓		✓	✓
Acceleration effects				✓
Disruption effects				✓

<u>Time of the delay</u>

The time of occurrence of the disputed delay event(s) relative to the current stage of the project determines whether a retrospective or prospective methodology should be used. The question to ask is: *Is the methodology being used to assess delay before its actual occurrence?* If **Yes**, then prospective methodology is appropriate and thus should be rated 1.0 and retrospective methods 0.0. Opposite rating should be allotted if the delays are being analysed after they have occurred.

Project characteristics criteria

These criteria include complexity of the project, the amount in dispute, size of project, duration of the project and number of delaying events. More sophisticated methods are warranted for instances where these characteristics are assessed to be high. For instance, if the project whose claims are disputed is a short duration linear project of say less than 6 months with say less than 5 delay events of claims value of less than say £50,000, then a simple As planned vr As-built methodology may be suitable to use than a more detailed Window analysis approach. On the other hand, an opposite rating should be allotted to the methodologies for the case of a large-sized project of long duration (say over 6 years) with very complex activity interrelationships, having tens or hundreds of delay events and significant claims value of say over £1m.

Figure 8.3 compares the suitability of the various DAMs against these project characteristics criteria. To rate a methodology for each of these criterion, a number on the 1-10 scale is first selected in reflection of the characteristics of the project in dispute. A vertical should then be drawn through this number and the methodology that falls in line with this vertical or very close to it will be the most suitable method with a rate of 10/10 = 1.0. The other methods are rated in proportion to their relative positions to this vertical.

Scale	1	2	3	4	5	6	7	8	9	10
	Very insignificant		Insignificant		Moderate		Significant		Very significant	
Size of project (in terms of contract sum)	<£500k		£500-£10m		£11m-£49m		£50m-£100m		>£100m	
Duration of project	<6 months		<6-12 months		<1-3 years		<4-6 years		>6 years	
Number of delay events	<5		5 - 10		11- 20		21- 50		>50	
Amount in dispute	<50k		50k-199k		200k-499k		500k-1m		>1m	
Complexity of project (in terms of activity relationships)	Very low		Low		Moderate		High		Very High	

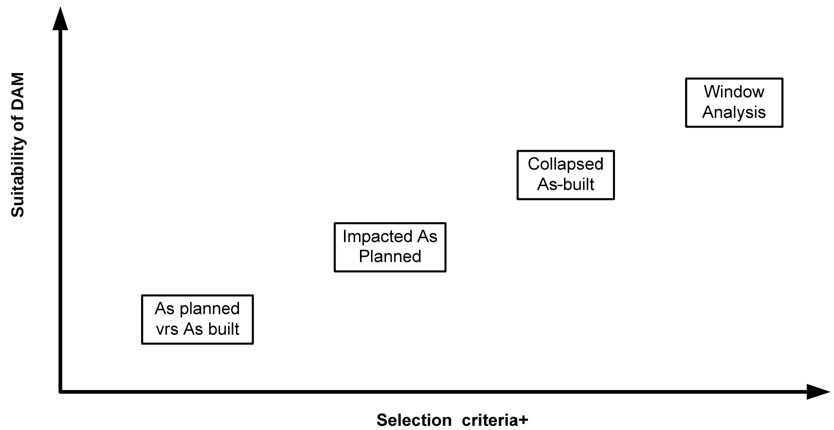

Figure 8.3 Suitability of DAMs against project characteristics criteria

+ the selection criteria are: Project complexity, Size of the project, Duration of the project, Number of delaying events, Cost of using technique, Skills of the analyst and the amount in dispute

Nature of delaying events

The nature of the delays experienced also makes the use of certain methodologies more appropriate than others. The sophisticated methods are capable of dealing with more complex situations than the simplistic ones. The capabilities of the various DAMs in dealing with typical characteristics of delays are shown in Table 8.7. To rate a methodology, the question is: *Which of these characteristics best describe the delays encountered?* Using Table 8.7 as a guide, the percentage of delay characteristics that a given methodology is able to handle is calculate to represent the suitability score for that methodology.

Table 8.7 Capabilities of DAMs in dealing with important characteristics of delays

Characteristics of the delay	As Planned vrs As Built	Impacted As Planned	Collapsed As Built	Window analysis
Delays occurred concurrently with others				✓
Delays caused much changes in construction logic				✓
Cause of delay is clearly definable	✓	✓	✓	✓
Delay caused productivity losses				✓
Delay caused acceleration				✓
Delays limited to specific definitive activities	✓	✓	✓	✓

The other party to the claim

Experience with the other party in previous claims matters or in prior settlement of the claims in question could inform the analyst of the extent to which the various DAMs are suitable to use. The question to ask in rating each methodology is thus: *Has the methodology been used in prior settlement of claims dispute with the other party without success?* If **Yes**, rate the methodology 0.0, otherwise rate it 1.0.

The skills of the analyst

Analysts are likely to incline toward the methodology which they are more knowledgeable and abreast with than those that they have very little experience with its use. Therefore the question to ask here is: *Does the analyst have the required knowledge and skills for implementing the methodology being rated?* If **Yes** rate 1.0, or else rate 0.0.

Cost of using the technique

To rate a methodology on this criterion, the question to ask is: *Is the expense involved in using the methodology within what is budgeted for?* If No, rate the least expensive method 1.0 (as it's the most suitable) and the most expensive as 0.0. Figure 8.3 provides a guide on the cost of using available DAMs relative to each other.

8.4.7 Limitations and Capabilities of the model

A major limitation of the model is the fact that the rating of the methodologies against each of the selection criterion requires many subjective decisions. To minimise this subjectivity and ensure that the model generates reliable results it is suggested that the analysts consult with relevant parties to discuss rating issues and agree on the rate to be assigned for each methodology. Another important concern is the need for analysts to consider all the selection factors in the model, although in some claims cases not all factors will be applicable or relevant. Notwithstanding these limitations, the model provides analysts with a comprehensive framework for selecting the right DAM for any claims situation. By this, they can justify their choice of a methodology to their client or triers-of-fact in a rational and balance manner. For further information on the model's limitations and its applicability in practice, it was forwarded to DD analysis experts for their comments. This validation is reported in the next chapter.

8.5 Summary

The existence of more than one acceptable methodology available for analysing delay claims has created the problem of which is the correct methodology for delay

analysis. This situation is made worse by the lack of a decision tool for assisting practitioners in resolving this problem. To improve the current practice where analysts often rely on their own experience and intuition for the selection, this chapter presented a decision model for aiding the selection process.

The development of this model involved, first reviewing existing decision tools and then selecting scoring multi-attribute analysis technique as the most appropriate tool for the model. Using this technique, a model consisting of five main processes was constructed. It involves rating competing DAMs on 18 selection criteria identified as relevant from a thorough review on the body of literature on DD and a questionnaire survey of acknowledged delay analysis experts in the UK and the US. The ratings from all the criteria are then multiplied by their respective weightings to obtain the suitability scores of the various methodologies. The total suitability score for each methodology is then computed by summing up all the suitability scores from the various criteria. By this approach, analysts can now methodically consider, articulate and apply their judgements to arrive at a rational decision concerning the appropriate DAM for a given claims situation.

To test for the validity of the model, it was presented to DD analysis experts for their comments on its significance to the construction industry, adequacy and applicability in practice as reported in Chapter 9.

CHAPTER NINE

9 VALIDATION OF DAM SELECTION MODEL

9.1 Introduction

Validation is a key part of model development process which increases confidence in the model and make it more valuable (Kennedy, *et al*, 2005). Thus, the developed DAM selection model, reported in the preceding chapter, was sent to DDA experts in the UK for their comments, as a means of validating the model. This chapter reports on the validation process and its findings. However, as background information, the chapter first outlines what is meant by validation, the various techniques available for performing it and the rationale behind the adoption of the technique used for validating this model.

9.2 Validation and its Techniques

There are many perspectives regarding the importance of validation in research, its definition, terms to describe it and the techniques for establishing it (Creswell, 2007). Given the many perspectives, Winter (2000) argue that "validation" is not a single, fixed or universal concept, but rather a contingent construct, inevitably grounded in the process and intentions of particular research projects and methodologies.

From modelling standpoint, validation is the process of defining whether the model is a meaningful and accurate representation of the real system in a particular problem domain (Borenstein, 1998). Unlike model verification, which is concerned with developing the model right, validation is concerned with developing the right model, (Gass, 1983; Kennedy, *et al*, 2005). It thus attempts to establish how closely the

model mirrors the perceived reality of the model user/developer team (Gass, 1983). Sargent (1998) argue that a model is developed for a specific purpose (or application) so its validity should be determined with respect to that purpose. The main purpose of validation is to get a better understanding of the model's capabilities, limitations and appropriateness in addressing the problem being modelled (Macal, 2005). These insights are often used to improve the model to an acceptable standard. In addition, they enable the modeller to meet certain criticisms of the model such as omissions and assumptions used; and help instil confidence in the model's output (Gass, 1983). However, it is often too costly and time-consuming to determine that a model is *absolutely* valid over the complete domain of its intended applicability (Sargent, 1998). Perhaps, this is because models are inherently unable to totally reproduce or predict the real environment (Gass, 1983). Thus, the validation process is often not aim at achieving absolute validity but rather confined to checking for *Operational Validity*. This validity concerns the process of establishing that the model's output behaviour has sufficient accuracy for the model's intended purpose over the domain of the model's intended applicability (Sargent, 1998). Other elements that concern operational validity include establishing whether the model (Gass, 1983): (i) offer a reasonable improvement in terms of net cost savings (ii) is robust enough that a user would find it difficult to make it yield an ostensibly wrong solution.

There are various techniques for validating a model, each of which can be used either subjectively or objectively, the latter referring to the use of some type of statistical or mathematical procedures (Sargent, 1998; Qureshi *et al.*, 1999). The basic idea behind any of these techniques is the accumulation evidence regarding the credibility and applicability of the model by an independent, interested party (Gass, 1983). It is

common to use a combination of the techniques when validating a model. Brief descriptions of these techniques, as defined in the literature (Gass, 1983; Sargent, 1998; Kennedy *et al*., 2005), are presented follows.

Animation*:* Watching a visual or graphical animation of the model's operational behaviour and comparing this with how the actual system behaves.

Comparison to Other Models*:* The output of the model being validated is compared to the results of other valid models of the actual system. This is applicable if such valid models are already available.

Degenerate Tests*:* The model behaviour is known to degenerate at certain situations. The model can be tested to see if it degenerates as expected by simulating such situations in the model using appropriate selection of values of the input and internal parameters.

Extreme Condition Tests: Similar to the degeneracy tests, the model can be tested by running it under extreme conditions to see if the model would behave as would be expected.

Event Validity: This technique is by comparing the "events" of occurrences of the model being validated to those of the real system to determine if they are similar.

Face Validity: This is by asking people who are knowledgeable about the system whether the model and/or its behaviour are reasonable. This technique can be used in

determining if the logic in the conceptual model is correct and if a model's input-output relationships are reasonable.

Fixed Values: By using fixed values (e.g., constants) for various model input and internal variables and parameters, the results of the model can be checked against easily calculated values.

Historical Data Validation: If historical data exist (or if data are collected on a system for building or testing the model), part of the data is used to build the model and the remaining data are used to determine (test) whether the model behaves as the system does.

Internal Validity: This is by running several replications of the model to determine the amount of internal variability in the model. A high amount of variability is an indication of lack of consistency and this may cause the model's results to be questionable and, if typical of the problem entity, may question the appropriateness of the policy or system being investigated.

Sensitivity Analysis: This technique consists of changing the values of the input and internal parameters of a model to determine the effect upon the model's behaviour and its output. The same relationships should occur in the model as in the real system. Those parameters that are sensitive, i.e., cause significant changes in the model's behaviour or output, should be made sufficiently accurate prior to using the model. This may require iterations in model development.

Predictive Validation: This technique consist of using the model to predict (forecast) the system behaviour, and then comparing the system's behaviour and the model's forecast to determine if they are the same. The system data may come from an operational system or from experiments performed on the system.

Traces: The behaviour of different types of specific entities in the model is traced (followed) through the model to determine if the model's logic is correct and if the necessary accuracy is obtained.

Turing Tests: People who are knowledgeable about the operations of a system are asked if they can discriminate between system and model outputs. Inability to discriminate between these outputs is an indication that the model is valid.

9.2.1 The technique adopted for validating the DAM selection model

According to Gass (1983), the appropriate technique to use for validating a model mainly depends on the real world aspect being analysed and the type of model being used. Consideration of the various techniques suggests *face validity* or expert opinion as the only appropriate techniques for validating the developed DAM selection model, mainly because no real-system data were available. Also, the aim of this study to validate the model for industry-wide application also makes this approach more suitable than the others. The objectives of expert opinion validation are to assess the feasibility of the model in terms of its adequacy and clarity, and to ensure that the model is reasonably robust and will be acceptable to users, much in the same spirit as member checking or validation in qualitative research (Bloor, 1997; Creswell, 2007).

Three options for carrying out the validation were considered: (i) focus group (ii) interviews and (iii) postal surveys. The use of focus group or interviews was handicapped by the time and cost constraints of the research, leaving postal survey as the most appropriate option. Problems associated with postal surveys such as the restrictive nature of the questionnaire and lack of opportunity to clarify respondents' doubts were overcome by carefully designing the questionnaire and including with it a worked example on the application of the model to clarify any misunderstandings the experts may have.

The following sections describe the detailed procedure of the validation exercise, which includes the application of the model to a hypothetical case study, development of validation questionnaire, selection of experts, administration of the questionnaire and the findings.

9.3 Application of the model to a hypothetical case study

The worked example for elucidating the application of the model in practice involves the application of the model to a hypothetical but realistic scenario of a construction delay claims problem. The scenario assumed for the worked example is defined as follows.

9.3.1 Case study scenario

The project assumed is a £200 million contract for the construction of a new liquid waste treatment plant for a Metro city. The project consisted of considerable amount of construction work with scope of over 5000 activities. This involved the construction of a number of treatment facilities organised in an intricate series to work

collectively for the reduction of inflow waste concentration to an acceptable standard. Also included was the construction of a three-storey operations house for the control and management of the plant.

The agreed contract duration for the project was 6 years but this was overrun by 20 weeks due to a number of DD events caused by the employer and the contractor. There were 43 of such events most of which were related to variations ordered by employer, design errors, unforeseen adverse ground conditions, delay in the release of necessary information to the contractor and contractor's labour and plant problems. The delays were clearly definable and limited to specific definitive activities, although some employer-caused delays occurred concurrently with other contractor-caused delays. In addition to causing delayed project completion, the delays also led to many changes in the original planned construction sequence, acceleration and loss of productivity effects. For instance, there were cases where the contractor had to move crew from one area to another due to resequencing of the works and other acceleration measures and this led to inefficiencies or loss of crew productivity.

Following these problems, the contractor issued claims for extension of time (EoT) of 15 weeks plus loss and expense of £2m. These claims were prepared using the Window analysis method and submitted couple of months after the occurrence of the last delay event, contrary to the contractual requirement of notifying the employer of such claims early. Unfortunately, the claims went unresolved till towards the end of the project when it was assessed by the employer's contract administrator (an Engineer) using the collapsed as-built methodology. The Engineer's response following the assessment was that the contractor is rather entitled to 10 weeks EoT and £800,000 for the loss and expense suffered. The contractor disagreed with this,

maintaining that the engineer's assessment was based on a methodology which is not appropriate to use for this claims and referred the matter to adjudication. To buttress this point, the contractor's delay analyst ought to prove to the adjudicator that his methodology is the most appropriate for this case, which can be asserted using the proposed DAM selection model.

Other facts surrounding the claims situation are:

i. The form of contract used did not expressingly provide for the use of a specific methodology for the analysis of delay claims. It however, stipulated that for the contractor to be entitled to EoT, delay events that are at the employer's risk should actually cause project delay. There was also no provision made in the contract for the cost of settling claims and disputes.
ii. In compliance with contract specifications, a baseline programme in CPM network format was prepared and submitted to the Employer by the contractor. This programme was, however, not updated on regular basis in the course of the project as the contract did not require so. Further, the baseline programme was found to be inadequate on two aspects: it did not include all the project activities and also some relevant activities were not defined at appropriate level of detail.
iii. An as-built programme showing how all the project activities were actually constructed was developed by the contractor at the end of the project.
iv. The contractor kept site dairy and monthly progress reports which contained information such as durations and start and finish dates on all the 43 delays and other relevant events.

9.3.2 Application of the model to the scenario

Having outlined the claims situation, the next step is to apply the model to select the best methodology among the following: As-planned vs As-built, Impacted As-planned, Collapsed As-built and Window Analysis. The model was applied to these methods in turn but only the detailed assessment of that of Window Analysis is presented here, as this is enough to illustrate the application of the model.

Step 1: Rating of Window Analysis against selection criteria

The rating is done by first comparing each selection criterion to a corresponding attribute of the window analysis method. Then using a scale of 0-1 ("1 for very suitable" and "0 for not suitable"), the method is given a rating score for each criterion in proportion to the extent to which the method is suitable to use based on the attribute and the criterion under consideration. The different attributes of the various methodologies presented in 8.3-8.9 and Figure 8.3 and reported in Chapter 8 were relied on in rating the methodologies against the various selection criteria.

Records availability (Rrec)

Table 7.3 shows all the important information required for the implementation of the various DAMs. In this example all the information required for applying window analysis are available except the dates of programme updates (i.e. 10 of the 11 required records are available). On the scale of 0-1 the suitability rate in respect of this criterion is R_{rec} = 10/11 = 0.91

Baseline programme availability (R_{bas})

Window analysis requires the use of a baseline programme and this was available for use in this case study. Therefore on the scale of 0-1, the suitability rating of the method for this criterion is, R_{bas} = 1.0

Nature of Baseline programme (R_{nab})

Table 8.4 outlines important baseline programming requirements for the use of the various DAMs. The baseline programme of this case study was deficient in two of these requirements (i.e. 3 of the 5 relevant requirements were satisfied by the programme). The suitability rating on the 0-1 scale is thus, R_{nab} = 3/5 = 0.60

Updated programme availability (R_{upa})

Table 8.5 outlines important programmes updates required for the use of some DAMs. For this case study, one of these requirements was lacking, i.e. the absence of regular programme updates. Since 1 of the 2 requirements was not available, the suitability rating for the method on the 0-1 scale is, R_{upa} = 1/2 = 0.50

Applicable legislation (R_{app})

It is assumed in this example that no legal procedures or rules were required to be followed by the disputing parties which could have affected the use of Window analysis. It is therefore very suitable to use this methodology and so rates highest on the 1-0 scale i.e. R_{app} = 1.0

Form of contract (R_{fmc})

The terms of the contract require that the delay analysis be based upon the actual effect of the delays on project completion. Therefore the methodology suitable for use

should be one of retrospective analysis, example of which includes the Window analysis method. Thus on the scale of 0-1, the rating of the methodology on this criterion, R_{fmc} = 1.0

Dispute resolution forum (R_{drf})

It is assumed in this example that the window analysis method is one of the methods acceptable for use in adjudication. Therefore the methodology's suitability rating on this criterion using the scale of 0-1 is R_{drf} = 1.0

The reason for the delay analysis (R_{rda})

Table 8.6 shows the capabilities of the methodologies in proving important delay claims issues. The disputes in this case concerned claims on time extensions, acceleration, disruption and prolongation cost. Since window analysis is capable of proving all these entitlements, it is rated very suitable on the 0-1 scale for this criteria i.e. R_{rda} = 1.0

Time of the delay (R_{tmd})

The time of the delay relative to the current stage of the project requires that a retrospective analysis of delay be performed but not prospective analysis. Window analysis is a retrospective methodology and so rates very suitable on the 0-1 scale, i.e. R_{tmd} = 1.0

Complexity of the project (R_{cxp})

Figure 8.3 compares the suitability of the various DAMs against a number of project characteristics criteria. On project complexity of this case study, the scale number that

best describes it is 10 as the scenario description suggests that the dependencies between the activities must be very complex. A vertical through this number falls in line with the window analysis method, making it the most suitable method in respect of this criteria and thus rated, R_{cxp} = 10/10 = 1.0.

The amount in dispute (R_{amd})

The amount in dispute for this case study is considered significant. This requires the use of a methodology that is free of major weaknesses or able to produce accurate results in the allocation of delay responsibilities. Figure 8.3 shows Window analysis to be the most suitable for such case and thus rated R_{amd} = 1.0

Duration and Size of the project (R_{drt} & R_{sze})

Based on the classification set out in Figure 8.3, the example project is considered very large in size and very long in duration. By extrapolation, windows analysis appears to be the most suitable method to use and thus its rating for these criteria are, R_{drt} = 1.0 and R_{sze} = 1.0

Number of delaying events (R_{nmd})

The number of delays in this case study is 43, which is less than the set threshold beyond which window analysis is most suitable to use (see Fig. 8.3.). Therefore by extrapolation the suitability rating of the method on this criteria is R_{nde} = 43/50 = 0.86

Nature of delaying events (R_{nad})

The capabilities of the various DAMs in dealing with important characteristics of delays are shown in Table 8.7. As can be seen, Window analysis is capable of dealing with concurrent delays and delays that caused acceleration effects and loss of

productivity. Since these were issues of concern in this example, window analysis is very suitable to use and so rates highest on the 0-1 scale i.e. R_{nad} = 1.0

The other party to the claim (R_{opc})

It is assumed in this case study that there was no prior unsuccessful settlement of the claims in which Window analysis was employed. It was therefore very suitable to use this methodology and thus rates, R_{opc} = 1.0

The skills of the analyst (R_{skl})

It is assumed for this case study that the analyst was very knowledgeable and skilled in the use of window analysis. Therefore it is very suitable to employ this method and so rated, R_{skl} = 1.0

Cost of using the technique (R_{cst})

Since the cost of resolving the claims was not budgeted for in the contract, the most suitable methodology for this study will be the one which is least expensive to use. Fig. 8.3 shows that Window analysis is the most expensive method and thus ranks lowest on the scale of 1-10. Therefore its suitability rating on this criteria is, R_{cst} = 1/10 = 0.1

Step 2: Window analysis suitability scores

Table 9.1 shows the suitability scores of Window analysis for each of the selection criterion obtained by multiplying each of the ratings for the criteria and their corresponding weightings. The total sum of all these scores is **10.22**

Table 9.1 Suitability Scores of Window Analysis

Group Factor	Selection Factor	Weight	Rating	Suitability Score
Record availability	Record availability	1	0.91	0.91
Baseline programme characteristics	Baseline programme availability	0.86	1.00	0.86
	Nature of Baseline programme	0.73	0.60	0.44
Contractual Requirements	Updated programmes availability	0.72	0.50	0.36
	Applicable legislation	0.37	1.00	0.37
	Form of contract	0.61	1.00	0.61
	Dispute resolution forum	0.56	1.00	0.56
Timing of the analysis	Reason for the analysis	0.63	1.00	0.63
	Time of the delay	0.64	1.00	0.64
Project characteristics	Project complexity	0.67	1.00	0.67
	The amount in dispute	0.75	1.00	0.75
	Size of the project	0.52	1.00	0.52
	Duration of the project	0.47	1.00	0.47
	Nature of delaying events	0.66	1.00	0.66
	Number of delaying events	0.68	0.86	0.58
	The other party to the claim.	0.46	1.00	0.46
Cost Proportionality	Cost of using method	0.59	0.10	0.06
	Skills of the analyst	0.67	1.00	0.67
		Total suitability score		**10.22**

Step 3: Selecting the most appropriate methodology

The above procedure was repeated for the remaining three methodologies to determine their total suitability scores, the results of which are shown in Table 9.2. The methodology with the highest total score was Window Analysis and so is the most appropriate methodology to use for the claim.

Table 9.2 Total suitability scores of the DAMs

Methodology	Total Suitability score
As Planned vrs As Built	8.38
Impacted As Planned	7.71
Collapsed As Built	9.87
Window analysis	10.22

9.4 Development of validation questionnaire

The second stage of the validation process was to develop a questionnaire indicating the areas where experts' views or comments are sought. The questionnaire was designed bearing in mind a number of criteria for validating a model including (Morris, 1979, Gass, 1983; Macal, 2005):

Accuracy and precision - can the model accurately and precisely select an appropriate delay analysis methodology for any given claims situation?

Completeness – does the model include all important decision variables required in the selection of delay analysis methodologies?

Comprehensibility – is the model simple and understandable to the intended users?

Cost effectiveness – does the cost involved in implementing the model outweigh its potential benefits?

The questionnaire also made provision for experts to express their comments on the model in general or on specific aspects of it. A copy of the questionnaire is set out in Appendix E.

9.5 Selection of the experts and response

For the model to be of acceptable standard to those in the field of delay analysis, it is essential that the validation generates useful and relevant comments from relevant experts. This can only be achieved if the experts chosen to participate in the validation have the required expertise. In view of this, the experts were selected from the list of practitioners who responded to the postal questionnaire survey based on the following

criteria: relevant expertise, relevant experience and academic and professional qualifications.

The use of the previous survey's respondents list as a sample frame has two main advantages. Firstly, most of the practitioners in this list were individuals in senior positions from construction and consulting firms with relevant expertise and experience in claims preparations and assessments. Secondly, their prior involvement in the earlier survey makes them familiar with this research, which will ensure good response rate. Prior to sending out the questionnaire, letters were sent to the experts requesting for their kind assistance in the validation exercise. Following this, a brief description of the model incorporating the work example was send out via post to 25 selected experts. The mail also included the validation questionnaire and a cover letter, stating the purpose of the research, the validation process and what was expected of them.

9.6 Analysis of experts' response

Of the experts contacted, 6 responded to the survey. Table 9.3 shows the profile of these experts in terms of their organisation, job designation, area of expertise, qualifications and years of experience in delay analysis. As can be seen, the experts are all actively involved in delay analysis within consulting firms specialising in this area of construction discipline. They possess relevant qualifications and their total combined construction industry experience is over 96 years.

Table 9.3: Profile of the validation experts

Expert	Organisation	Designation	Expertise	Qualification	Years of experience
1	Quantity surveying firm	Director	Delay analysis	BSc(CEng), LLM(Const. Law), FCIOB, FCIArb,	16
2	Dispute resolution firm	Director	Consultant planner	PhD, MSc (Const. Mngt), DipArb., FCIOB, FCIArb	14
3	Construction law firm	Partner	Construction law	BSc (Hons), LLM, FRICS, FCIArb, MCIOB, Solicitor	18
4	Quantity surveying firm	Director	Delay analysis	BSc, DipArb, FRICS, FCIArb, MAPM	20
5	Construction contracting consultants	Executive Director	Expert Witness	PhD, BSc, MSc, DipArb, FRICS, FCIArb, FAE	13
6	Firm of forensic planners	Associate Director	Planning and programming	BSc, MAE, FPEO, MAACEI, MSCL, PMI.	15

As mentioned earlier on, the respondents were asked in a structured, semi-closed questionnaire to comment on the model. In addition to offering ticked-box responses, some of the experts provided their own comments about the model. All the responses received were, to a large extent, positive. A summary of the responses to the various questions in the questionnaire are set out in Table 9.4.

Table 9.4 Summary of response from experts

Validation Criteria	Expert response					
	1	2	3	4	5	6
Model address important problem in the field of DD analysis?	Yes, quite significant	Yes, quite significant	Yes, quite significant	Yes, but not significant	Yes, but not significant	Yes, quite significant
Models Capability in assisting in DAM selection	Yes capable	Yes, highly capable	Yes, capable	No, not capable,	Yes, highly capable,	Yes, highly capable,
Comprehensibility of the model	Yes	Yes	Yes	Yes	Yes	Yes
Resources needed to apply the model	Wouldn't be too costly to operate	Wouldn't be too costly to operate	Benefits of using it justifies any resource requirements	Wouldn't be too costly to operate	Wouldn't be too costly to operate	Wouldn't be too costly to operate
Completeness of the model	Yes	Yes	Yes	Yes	No	Yes
Scale for rating methodologies against criteria	Very suitable	not sure of suitability	suitable	suitable	not sure of suitability	Very suitable
Approaches/methods for evaluating the criteria in methodology rating	Not sure of its suitability	suitable	suitable	suitable	not sure of suitability	Very suitable
Attributes of DAMs methodologies defined	Not sure of its suitability	suitable	Very suitable	suitable	suitable	Very suitable

As can be observed from the table, most of the experts agreed that the model addresses an important problem in the field of delay analysis. Concerning its capability in performing its intended function accurately, most of the experts were of the opinion that it is capable. This suggests that the model would be regarded by practitioners as a very useful tool for DAM selection.

In terms of the model's completeness, most experts felt that the model is comprehensive and detailed, touching on all relevant criteria for selecting DAM. With regard to comprehensibility, most experts found the model to be clear and simple to understand and implement. One expert noted "*it has covered a very complex aspect of delay analysis in a simple and logical manner, which I think would not be difficult to apply in practice*". However, an issue of concern raised by few of the experts that can cause implementation difficulties relates to the degree of judgement required to reach agreement on the rating of the methodologies. One stated that *"each party will press for their own case and interpret accordingly – even on the quality/availability of records*". The author's view is that this is not likely to cause difficulties in situations where the model is being used by an analyst to justify the choice of a methodology to its clients. The author acknowledges and accepts that it will rather be problematic when analysts are using it to justify a methodology to a triers-of-fact or when disputing parties are using it to reach an agreement on the best methodology.

Most experts felt that the model would not be too costly to implement at current resource level. One expert commented that "*its implementation would not consume great resources and time and consequently its benefit would outweigh the costs".* The various approaches proposed for evaluating the selection criteria were found to

suitable. The scale for rating the methods was also found to be appropriate. Issues of concern raised relates to the attributes of the methodologies as defined in Tables 8.3 - 8.8 and Figure 8.3. One expert mentioned that the "*selection/definition of the methods of analysis and the question of what is required of a delay analysis are unresolved issues that will pose obstacles to the rating of the methodologies".* Another objection raised was *"each project will have its own view on the weights that have been assigned to the various selection criteria".* The author does agree with this in principle but considers the weightings to have sufficient objectivity, rigour and basis for generalisation over some period of time since they were views expressed by practitioners based on their many years of experience on projects. One expert recommended that for improve usage, the model must be computerised.

By and large the opinions of the experts were in favour of the model suggesting that the model would be regarded as valuable tool for selecting DAM. This represents a positive contribution to the body of knowledge and practice of delay analysis within construction organisations.

9.7 Summary

This chapter reports on the validation of the DAM selection model. The validation process involved first the application of the model to a hypothetical case study. This example application together with brief description of the model was then posted to acknowledged delay analysis experts within UK for their opinion on the significance of the model, its adequacy, completeness, comprehensibility and cost effectiveness.

Out of 25 experts who were sent questionnaires for the validation, only 6 responded. The majority of them were in favour of the model indicating that the model is a positive contribution to the subject of delay analysis in construction contracts. The main reservations expressed about the model concerned a potential difficulty of reaching agreement on the ratings of the methods as there is currently lack of agreement among practitioners as to the definition of the methods of delay analysis and what the application of each actually entails.

CHAPTER TEN

10 CONCLUSIONS AND RECOMMENDATIONS

10.1 Introduction

It is well documented that claims related to projects DD are now a major source of dispute in the construction industry. Consequently, there has been much desire to reduce or completely avoid this problem and this has created considerable research interest among researchers and practitioners. The studies so far have followed three main strands of research and expert commentary. The first group focuses on development of new methodologies for analysing DD or improvements in existing ones to address their weaknesses. The second, concerns with advocating for better risk management and project design to reduce the likelihood of changes or variations. The last group focuses on explaining and providing guidance on contentious contractual and legal matters related to DD claims.

Despite such attempts, DD analysis continues to pose great challenge to project parties. Stimulated by this, this research was initiated to investigate the current use of existing DD analysis methodologies in the UK and the associated problems. This was achieved through the use of an industry-wide questionnaire survey of construction organisations (reported in Chapter 6) and subsequent interviews with contracting firms (reported in Chapter 7). The purpose was to use the results from this investigation and that from review of the literature (reported in Chapters 3, 4 and 5), to develop a framework for improving DD analysis. Working from these sources of information, the developed framework entailed a model for selecting appropriate

DAM (presented and validated in Chapters 8 and 9, respectively) and suggested recommendations for promoting good practice (presented in this chapter). Also reported in this chapter are the major findings and conclusions from the previous chapters, which formed the basis of the recommendations. The final part of this chapter presents a number of recommendations for further research.

10.2 Research Findings and Conclusions

The primary data relied on in achieving the research aim and objectives came from 63 contractors and 67 consultants who took part in the questionnaire survey on use of DD analysis methodologies. Out of these, 15 contractors further participated in the subsequent interview; whilst 6 consultants participated in a later validation exercise in respect of the DAM selection model. The majority of the firms were large organisations with more than 16 years experience in dealing with DD claims. Also, majority of the respondents were at high levels of responsibility within their organisations. They were therefore ideally suited to participate and respond to the issues investigated in this research.

Drawing from the primary data collected and the literature review, the main research findings obtained and conclusions deduced in respect of the research objectives are as follows:

1. Resolving concurrent delays is a highly contentious issue, exacerbated by the fact that there is no common definition among practitioners as to what concurrent delay means. Despite this, there seem to be some accepted principles with regard to its effect on entitlement to extension of time and compensation to prolongation

cost (see Sections 3.2.1 and 3.2.2). The use of methodologies that are capable of resolving claims involving concurrent delays is thus an important consideration in DD analysis. Another contentious issue that influences DD analysis is the question of "who owns float". This issue, however, remains unresolved, particular in the UK where most of the contracts do not address it by way of defining the ownership.

2. An important issue related to float ownership is the question of whether contractors are entitled to time and cost compensations for employer–caused delays that prevent early completion, programmed by the contractor, even though completion is not delayed beyond the contractual completion date. The generally accepted view on this is that contractors are entitled to complete earlier than the specified contractual completion date but the employer is not obliged to provide information or other deliverables to ensure the former, without deliberately hindering the contractor.

3. Resolving delay claims involving employ-caused delays that occurred after the expiry of contractual completion date when the contractor is in culpable delay is also an important issue in DD analysis. The generally accepted approach for resolving this matter is the "net effect method", which is adding the amount of time taken by the delay to the date upon which the contractor should have finished the work, be it the original or adjusted completion date, even though this may be well before the date upon which the delay-events events occurred.

4. The majority of the respondents felt that DD claims are often left unresolved until nearer the end of the project or after, contrary to resolving it contemporaneously in the course of the project or as close in time to the occurrence of the delaying event (s), an often recommended practice (see Section 6.4). They also felt that their resolutions are often attended by considerable difficulties resulting in frequent disputes (see Section 6.5). These findings further confirmed the need for undertaking this research, which seeks to reduce or avoid such disputes through the development of a framework for improving current DD analysis.

5. The respondents indicated that the most frequent reasons for disputes over DD claim resolutions are: failure to establish causal link, followed by inadequate supporting documentation on quantum and then insufficient breakdown of claims amount. Inability to meet notice requirements by contractors was viewed as the least frequent reason (see Section 6.6). This suggests that an important area that requires much attention, if disputes on DD claim resolutions are to be avoided or reduced, is the methodologies for proving causation and recording keeping on site.

6. The preparation or assessment of DD claims is a multidisciplinary task involving different levels of inputs from commercial managers (or quantity surveyors), architects/engineers, project managers, planning engineers, estimators, construction lawyers and claims consultants. Quantity surveyors (QSs) make the greatest input in either claims preparation within construction firms or its assessment by employers' consulting team (see section 6.7). Their highest involvement within consulting firms, however, conflicts with the provision in

most forms of contract that the Architect/Engineer is the agent responsible for contractors' claims assessments. This implies that DD analysis is the domain of QSs, although with the development of user-friendly project planning software the task now appears to be the province of programmers or schedulers. There is therefore the need for attention to be given to QSs functions within employer organisations in terms of their roles in DD claims assessment, strategic management of this role and their training needs.

7. There is increasing recognition and acceptance of the use of CPM-based methodologies for DD analysis by UK courts. Whilst it is not clear from case law as to which of the available methodologies is most acceptable by the courts and how each should be applied appropriately, some important principles pertaining to their usage were identified (see Section 3.6). First, their application should be backed by: (i) good factual evidence; and (ii) effective presentation of that evidence through clear, methodical and transparent analysis. Second, those giving evidence in court in the capacity of an expert must ensure that their approach is balanced, objective, thorough, clear and sensible. These emphasise the need for keeping good project records and relying on DD analysis methodologies that are free of major flaws. Such practice will help diffuse misunderstandings or disputes that often surround DD analysis.

8. A number of methodologies for analysing delays (DAMs) have been reported in the literature. Not only are these referred to by different terminologies amongst practitioners and researchers, they also differ based on their mode of application, the type of programming technique and the baseline programme used. As such,

they produce different results of staggeringly different levels of accuracy when applied to a given claims situation. These differences contribute to the difficulties and disputes associated with DD analysis (see Section 5.3.1).

9. None of the existing DAMs is perfect as each has its own strengths and weaknesses. The more sophisticated methods (viz, Time Impact Analysis, Window Analysis, Collapsed As-built and Impacted as planned) are reported as being more accurate and reliable than the simplistic ones (viz, Global method, Net Impact Technique and As planned vrs As built), although the former group requires more expense, time, skills, resources and project records to operate than the latter.

10. There is also no single DAM that is universally acceptable for all claims situations. The most appropriate methodology for any given situation depends on a number of criteria. However, apart from the fact that these criteria may vary from analyst to analyst, they are qualitative, subjective and imprecise in nature, making their use in methodology selection open to challenge and disputes (see Sections 5.3.2 and 5.3.3). It was for this reason that, this research developed and validated a model for selecting appropriate DAM to aid practitioners in this decision-making task.

11. Like DAMs, the methodologies for analysing disruptions (DSAMs) are numerous and referred to by different names amongst practitioners. They vary based on different sources of information they relied on for analyses. None of them is perfect even though some are more reliable than others under certain

circumstances. Their acceptability or reliability depends upon the situation of the claims at hand (see Section 5.4).

12. In determining what framework (in a form of recommendations) might be useful for improving DD analysis, an area identified as important for investigation was the use of the existing methodologies in practice and associated problems (as Paragraphs 5 and 7 above suggest). The questionnaire survey employed for undertaking this investigation revealed the following:

    (i) The most well-known DAMs are the: As-Planned vs. As-Built, followed by Impacted As-planned, Global method and then the Net Impact technique i.e. the sophisticated methods, known to be the most powerful, were generally among the least known methodologies.

    (ii) The most widely used methodology, on the whole, was the As-Planned vs. As-Built followed by the Impacted As-planned, despite their reported numerous weaknesses. These methodologies most frequently expose claims to challenge, although they are those that most frequently lead to successful claims resolution. The reason for this irony is probably because, by virtue of their extensive use, they are likely to be the methods which most claims are finally resolved by.

    (iii) The Time Impact Analysis and Window Analysis methodologies, highly acclaimed in the literature as the most rigorous, are not widely used; although consulting firms tend to use them to a higher extent than

contractors. Despite their low rate of use, respondents recognised them as the most accurate and reliable methodologies corroborating the views in the literature. This suggests that tackling the problems that make it difficult to use these methodologies can bring about improvements in DD analysis and reduce disputes.

(iv) Respondents reported that the most frequent obstacles to the use of the methodologies are: lack of adequate project information, poorly updated programmes, baseline programme not being in CPM network form, high cost involved in the use of the techniques and difficulty in the use of the methods, in that order (see Section 6.8.5). These support an earlier findings from the literature that: poor baseline programmes, failure to update programmes, and inadequately updated programmes are major deficiencies in practice that affects smooth analysis and resolution of DD claims (see Section 4.2). Other sources of even more frustrating problems identified by the survey include: unhelpful attitude of project employers and their representatives, adversarial relationship between parties and lack of expertise to deal properly with DD claims (see Section 6.10).

(v) Given that no single DAM is universally appropriate for all claims situations, respondents indicated that the most appropriate methodology is dictated by eighteen (18) criteria. These have different degrees of importance in influencing methodology selection with the top five as: records availability, baseline programme availability, the amount in dispute, nature of baseline programme, and updated programme

availability; in that order. The 18 criteria were further grouped into 6 generic factors using factor analysis as: project characteristics, contractual requirements, characteristics of baseline programme, cost proportionality, timing of analysis and record availability (see Section 6.8.6).

(vi) The most well-known and widely used DSAMs are: the Global method, followed by the Modified Global Method and then the Industry Studies and Guidelines, although these have received a lot of criticisms from the courts and expert commentators on account of their numerous weaknesses. The Measured Mile Technique and the Earned Value Management, reported as the most rigorous methodologies, are however, not widely used in practice. Nevertheless, the respondents, by and large, recognised these methodologies as the most accurate and reliable supporting the views in the literature.

(vii) The respondents employ the various methodologies to the same extent as they are aware of them at significant correlations (see Sections 6.8.4 and 6.9.3). This suggests that promoting the use of the more accurate methodologies cannot only be engendered by improvements in record keeping and programming practice, but also by raising their awareness level among practitioners.

13. Problems with programming and record keeping practice are a major source of the difficulties with DD analysis as Paragraph 12(iv) above indicates.

Investigating the underlying causes of these problems using interviews identified the following:

(i) Most of the interviewees confirmed that in addition to making use of contract programmes as a control tool during construction, they also make important use of it in the assessment of progress, impact of variations, delays and disruptions (see Section 7.3).

(ii) Although majority mentioned that they often prepare baseline programmes and submit it to their employers or its representatives, they do so with very little involvement of the latter (see Section 7.4). As a result, issues on reliability of the programme (see Section 4.2.1) may cause difficulties later in the approval or acceptance of the programme by the employer or its representatives.

(iii) In addition to the baseline programme, contractors also produce other planning deliverables during preconstruction stage. However, manpower loading graphs, an important deliverable essential for DD analysis are often not produced. It was no surprise therefore that most interviewees further claimed that they often do not resource-load and level their baseline programmes. This practice does not make baseline programmes very reliable in their use for proving or refuting DD claims (see Section 7.5). Reasons given for such practice include that, it is: a time consuming and difficult exercise to do; not often part of clients' requirements; and not considered by parties as a critical requirement.

(iv) Most interviewees mentioned that they often generate their baseline programmes in linked bar chart format and gave reasons for this preference over CPM networks as being easy to prepare, use and maintained. Some contractors openly admitted that it is company culture to use linked bar chart format. However, this format has difficulties in clearly showing the links between activities when used in programming, particularly, works involving complex sequence of activities (see Section 7.2). This format is thus not very supportive in DD analysis.

(v) Interviewees mentioned that they always produce their programmes using computers with the most common programming software packages relied on for this as: *CS Project*, *Power Project*, *MS Project* and *Asta Teamplan,* the first being the most commonly used (see Section 7.2). The literature, however, suggests that these packages are not very rigorous in their use in DD analysis.

(vi) Most contractors claimed they update their programmes monthly but with no involvement of the employer or his representative. They also prepare and submit progress reports on monthly basis to the employer. However, these reports do not often contain all the relevant information on progress of the work, which are crucial information source for DD analysis.

(vii) Most interviewees claimed that they do not keep records on crew productivity on major activities. The main reasons given for this practice were, that: high resources are involved in keeping such records and staff often do not recognise the importance of such records.

10.3 Best Practice Recommendations

In the light of these findings, it can be concluded that in practice, contractors and consultants often resort to DD analysis methodologies that are incapable of producing results of high accuracy or reasonable precision/certainly, which is a recipe for disputes on DD claims. Problems related to programming and record keeping practice has made the use of more accurate methodologies less amenable as they require detailed and accurate programmes and project records to implement. To facilitate their use, thereby helping to reduce or avoid disputes, the following recommendations are suggested.

1. Employers have to make provisions in their contracts that will ensure that contractors submit a fully resource-loaded baseline programme in an appropriate format reflecting the true intentions of the contractor (see Sections 4.3.9 and 7.5). The contractor must prepare this using industry standard planning software and submit it electronically to the employer or its representative. The linked bar chart should be the required format to be used for projects that are not considered too complex in terms of activity relationships (see Sections 7.2). This format should also be used when producing hardcopies versions of the programme for purposes of site management and communication.

2. Provision should be made for a meeting between the contractor and the employer, prior to commencement of work, for joint assessment of the baseline programme. This assessment is intended for ensuring smooth approval of the baseline programme and agreement on some aspects of the programme and its management. It should involve a structured collaborative review process akin to value engineering approach. The outcome of the review would be to modify the programme if necessary or accept it as is. The key areas to consider in the review exercise include (see Section 4.2.1):

   (i) The planning software used: the software employed for programming the work should be appraised as to its appropriateness and agreement reached in accepting it or otherwise. Aspects of the software that should be agreed on are the appropriate project calendar and the planning units (work days or work weeks) to be used for planning.

   (ii) Project scope: the programme should be checked to ensure that it represents the entire project work. It should include all relevant activities relating to design, procurement, on-site construction, subcontractors' work and significant project milestones. The main source of reference for this checking should be the contract documents.

   (iii) Activity logic: activity dependency relationships should be reviewed for flaws and unreasonable constraints. Parties must be in agreement with any preferential or soft logic introduced. This will prevent artificial logic that can hide float or exaggerate delays.

(iv) Activity durations: review the various activities to ensure that their estimated durations are realistic. This will help check for incorrect activity start date, artificial activity durations that hides float and unrealistic early completion programme. A major source of information for this review is the method statement, assumptions made and experience. For this reason, it is recommended that contractors should be required to submit method statements as well. There must be agreement on all assumptions made in identifying the parameters and conditions used for estimating durations for major activities. These assumptions must be clearly documented as they eventually form the basis of the programme. There must also be an agreement on any contingencies factored into the programme for managing risk.

(v) Level of activity details**:** review to ensure that the level of detail is appropriate for managing the project and analysing delays. One way of achieving this is by finding out if each of the activities has an update capability or can be measured i.e. able to determine its percent completion during project execution. However, since the level of detail depends on factors such as the amount of information available for planning, phase of the project, duration and complexity of the project; it is recommended that a rolling wave planning technique be adopted by contractors. This permits detailed near-term planning and summary level planning of activities whose execution lie far in future.

3. Having reviewed the baseline programme, the next on the agenda should be directed towards resolving and reaching agreement on issues that can affect smooth management of the programme. These include (see Sections 3.3, 4.1 and 4.2.3):

the frequency of programme updating;

mode of updating the programme;

level of detail to be shown in updates;

float ownership and consumption;

the type of records to be kept; and

content and frequency of site progress reporting.

4. The contract should require that electronic copies of the accepted baseline programme and all subsequent updates, in separate files, be submitted in addition to hard copy versions. Each programme update should be accompanied by a detailed progress report describing any changes in the project activities, their logic and durations which are inconsistent with the previous progress report. This will enable the employer or its representative to review updated programmes for accuracy for the purposes of approving it (see Section 7.6).

5. Provision should also be made in the contract for the keeping of records that will provide adequate evidence on the causes of delay and/or disruptions and their impacts. Such records should include (see Sections 4.1 and 7.7):

(i) Site progress report: should provide information on the status of all activities in the programme, delays encountered, weather

conditions, changes experienced in working conditions due to DD and site resources information (labour, plant and materials). The report must be prepared and issued at regular frequencies as agreed during the joint review meeting.

(ii) Job cost report: Record of actual resources and expenditure based on progress, labour allocation sheets and associated costs; bid estimates and subcontractors' quotations used and project budget and its updates. For effective cost reporting, separate cost accounts should be established to capture the costs of resources expended in executing potential compensable events that can be readily identified and segregated from the original scope.

(iii) Records on actual working conditions, time periods during which these conditions occurred, their locations and all works performed under each working condition.

(iv) Records of crew productivity for major activities, variations ordered and their details, drawings and other necessary information requested and dates received and all project correspondence.

(v) Progress photographs or videotapes at critical times.

Following the above recommendations, parties can employ more reliable DAMs such as the Time Impact Analysis, which are capable of producing more accurate results. This will facilitate understanding and agreement among claims parties on the resolution thereby minimising the potential for disputes.

10.4 A model for selecting appropriate DAM

Although the above recommendations, if followed, would ensure the availability of meaningful records required for smooth resolution of DD claims, there are other factors in practice unrelated to records and programmes that may influence the kind of methodology analysts would want to use. Moreover, most forms of contract seldom specify the methodology that should be used for analysing delays either in the course of the project or after. Claim parties and their delay analysts therefore often adopt their preferred DAM for the analysis based on their own accumulated experience, expertise and intuition; which is a recipe for disputes (see Section 8.1).

Inspired by the need to address this problem, a model for the selection of an appropriate DAM has been developed. This is intended to serve as a tool for assisting analysts in justifying their choice of DAM to their clients and/or the trier-of-fact when the contract is silent on the method to use. Claim parties can also rely on it to arrive at balanced rather than partisan results if they have to come to an agreement on which DAM should be used for analysing the claims. The development of the model encompassed the following stages (see Section 8.4):

- Identification of selection criteria
- Development of flow chart indicating the model's procedure
- Identification of methods/approaches for evaluating the criteria
- Application of the model to a hypothetical case study and expert validation

<u>Identification of selection criteria</u>

The model is based on scoring competing DAMs on 18 selection criteria in reflection of the extent to which each methodology is suitable to use considering each of the

criteria in turn. These criteria were identified as relevant from a thorough review on the body of literature on DD analysis and a pilot questionnaire survey of acknowledged delay analysis experts. The main questionnaire survey that followed investigated their level of importance. Weights were then assigned to each criterion in reflection of their relative importance.

Development of flow chart indicating the model's procedure

A flown chart describing the entire selection process was developed to serve as a framework for the model. This involved going though three main steps: rating the methodologies against each criterion, computing suitability scores of the methodologies and selecting the most appropriate methodology. For each methodology, a numerical output (total suitability score) representing its suitability for use is generated by the model. The methodology with the highest total score represents the most appropriate methodology.

Identification of methods/approaches for evaluating criteria

In order to compute the suitability scores, the various methodologies are to be rated first on a scale of 0-1 based on their attributes in respect of each of the selection criteria. The methodologies have different attributes which have to be known by the analysts to enable him/her rate them accurately. The attributes of the four common methodologies have been gleaned from the literature and most presented in a form of tables and figures. The rating is facilitated by answering a number of questions as to the extent to which a methodology is suitable for use for a given criterion. These questions together with the various attributes form a standardised set of operations for rating the methods.

Application of the model to a hypothetical case study and expert validation

The selection model was elucidated through its application to a hypothetical but realistic scenario of a construction delay claims dispute. To ensure that the model is valid for use in practice, it was further subjected to validation via experts' review in a questionnaire survey. The experts were required to express their views on the model in terms of its significance to the industry, adequacy, completeness, comprehensibility and cost effectiveness. The majority of the respondents were in favour of the model proving that the model is a positive contribution to the subject of delay analysis in construction contracts. The main objection expressed concerned a potential difficulty of reaching agreement on the ratings of the methods as there is currently lack of agreement among practitioners as to the definition of the various DAMs and what the application of each actually entails.

10.5 Recommendations for further research

The proposed DAM selection model has some limitations most of which are the issues of concern raised by the experts in the validation. Further investigations for its most optimum implementation are therefore required. The key areas for this further research are discussed as follows.

The relative importance weights used in the model were obtained from a cross-sectional survey of claims practitioners from construction organisations. Such coefficients are, however, likely to change with time due to the dynamic nature of the industry which will affect the problem setting of methodology selection. For this reason, it is recommended that similar surveys be repeated at periodic intervals in order to update the model to maintain its accuracy and applicability over time.

Another consideration that can render the model more useful is the need for standards for DAMs; a common ground from which their definitions and applications can be universally understood and accepted. Such standards require an extensive research across industry, towards establishing what constitutes the most acceptable procedures for implementing the recognised DAMs and what the various names given to them refer to.

The following points have also been identified as areas worthy of further research:

1. Like DAMs, the selection of appropriate DSAMs is also dictated by a number of factors. This has contributed in part to the long standing debate surrounding the appropriateness of using these methodologies, particularly the use of the global method. Consequently, a research into these factors towards the development of appropriate guidelines or decision tools for selecting the most appropriate methodology would go a long way to assist practitioners and help reduce the likelihood of disputes.

2. Other relevant planning and programming matters that were not investigated in-depth in this research include: common forms of contracts, programming specifications/provisions stipulated therein, the role of contract administrators in managing programmes and records on behalf of employers and what they actually do (see Section 4.3). Investigations into these would shed more light on how best DD analysis can be improved to reduce disputes.

3. The whole process of how contractors manage and control their cost information on site significantly influences the ability to resolve DD claims amicably but has so far received very little attention. This area thus requires further investigation.

4. The scope of this research was limited to the analysis of DD claims that are prepared by main contractors and assessed by employers' consultants. There is evidence, however, that subcontractors are also often involved in such claims but their views were not captured due to a potential complication factor and time and cost constrains. Further research is thus required in investigating this area.

5. There is the belief that some of the problems with DD analysis are attributable to certain inherent features of existing programming software packages which can be abused readily. Such abuse leads to less transparent analysis and thus creates room for challenge with ensuing disputes. To address this problem, research is required to investigate, among others, the capabilities and functionality of the software packages in use.

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Appendix A

- **Cover letter for postal questionnaire survey**
- **Copy of postal survey questionnaire**

Cover letter for postal questionnaire survey

Author's Address

Name
Company
Address

5th August 2006

Dear ………

ASSISTANCE FOR RESEARCH SURVEY ON THE ANALYSIS OF DELAY AND DISRUPTION (DD) CLAIMS

Delay and Disruption (DD) claims on construction and engineering projects are some of the most expensive, difficult, controversial and time consuming disputes to resolve in recent times. In a bid to address the problems associated with the analysis of DD claims, the School of Engineering and the Built Environment of the University of Wolverhampton is sponsoring a study into the current use of DD analysis methodologies and the associated problems affecting their usage. This research thus aims to understand the practice and methodologies currently adopted in the analysis of DD claims in the UK construction industry. The outcome of this research will hopefully result in an important framework that will help project participants to improve on the resolution of DD claims.

To achieve these aims, I would be most grateful if you could encourage a member(s) of staff with relevant experience of DD claims preparation and settlement to participate in the survey. You may make multiple copies of this questionnaire in case of multiple respondents. In addition to answers to specific questions, views on any other matters relevant to the aims of the study are most welcome. There are no correct or incorrect responses, only much-needed expert opinion.

I would be most grateful if the completed questionnaire is returned using the enclosed stamped addressed envelope by 31/08/2006. Should you wish to learn more about the research project, please do not hesitate to contact me. All information received will be treated as strictly confidential and will not be disclosed in any way.

We do appreciate that the questionnaire will take some of your valuable time but without your kind and expert input the research objectives aimed at cannot be realised. To this end, we would like to thank you very much for your valued and kind participation.

Yours faithfully,

Nuhu Braimah
Research Student

School of Engineering and the
Built Environment (SEBE)
University of Wolverhampton

A QUESTIONAIRE TO INVESTIGATE THE CURRENT PRACTICES ON THE ANALYSES OF DELAY AND DISRUPTION (DD) CLAIMS

The main aim of the questionnaire is to gather and assess your views and attitudes in relation to the use of DD analysis methodologies for preparing claims. The questionnaire is in three (3) parts. **Section A** seeks to collect information on your organisation's background and general issues on DD claims. **Sections B and C** ask for your opinions on the usage of the various delay and disruption analysis methodologies respectively. The various methodologies may be known by different names amongst practitioners. For this reason, a brief explanation of each is presented in the attached notes (Appendix A & B) as reference.

We would very much appreciate if you could please spare some few minutes to complete the questionnaire. There are no correct or incorrect responses, only your much-needed opinion. The major benefit to participants is identified as access to the subsequent results, which will enable you to improve on your firm's approach to DD analysis. Consequently, the questionnaire requests for background information of the participant (is optional) for relaying the research findings to interested participants and for purposes of follow-ups.

We do appreciate that the questionnaire will take some of your valuable time but without your kind and expert input the research objectives aimed at improving the resolution of DD claims cannot be realised. To this end, we would like to thank you very much for your valued and kind consideration.

Please return the completed questionnaire in the self-addressed stamped envelope provided to the address below or return it by fax.

Nuhu Braimah
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Section A: General Information

1. Which of the following best describes the nature of your organisation's activities? (Please tick ✓ one box).

Building contracting only	❑	Civil Engineering contracting only	❑
Building and Civil Engineering contracting	❑	Other (please specify) ____________________	

2. Please give an indication of the size of your organisation in terms of annual turnover. (Please tick ✓one box).

Less than £5m	❑	£26m - £100m	❑
£5m - £25m	❑	greater than £100m	❑

3. Please indicate which of the following best describes your job in the company. (Please tick ✓ one box).

Planning	❑	Site management	❑
Estimating	❑	External Claims Consultant	❑
Commercial Management or Quantity surveying (QS)	❑	Other (please specify) ____________________	

4. Please indicate your personal experience of the following listed functions (Please tick ✓ one box in each row for each function relevant to you).

	Experience (in years)					
	0	< 5	5-10	11-20	21-30	>31
Estimating	❑	❑	❑	❑	❑	❑
Programming	❑	❑	❑	❑	❑	❑
Site management	❑	❑	❑	❑	❑	❑
Measurement	❑	❑	❑	❑	❑	❑
Claim preparation	❑	❑	❑	❑	❑	❑
Legal Support /Contract Management	❑	❑	❑	❑	❑	❑

5. Please indicate the level of involvement of the following parties in the preparation of DD claims generally (please tick ✓).

	Least Involvement 1	2	3	4	*Highest Involvement* 5
Head of Commercial Management (or QS) Dept. or his/her nominee	❑	❑	❑	❑	❑
Head of Estimating Dept. or his/her nominee	❑	❑	❑	❑	❑
Site Manager (or Contractor's Project Manager)	❑	❑	❑	❑	❑
Head of Planning Dept. or his/her nominee	❑	❑	❑	❑	❑
External Claims Consultant	❑	❑	❑	❑	❑
In-house lawyer (Legal Counsel)	❑	❑	❑	❑	❑
External lawyer (Legal Counsel)	❑	❑	❑	❑	❑
Other (please specify) ____________________	❑	❑	❑	❑	❑

6. Please indicate the extent of your agreement or disagreement with the following statements about DD claims in practice (please tick ✓).					
	Strongly disagree 1	2	3	4	*Strongly agree* 5
a). The analysis and resolution of most DD claims are left unresolved until nearer the end of the project or after completion before resolving it	❑	❑	❑	❑	❑
b). The resolution of DD claims are often attended by considerable difficulties thereby causing disputes	❑	❑	❑	❑	❑

7. Please indicate the frequency with which each of the following has been the reason for unsatisfactory resolution of your DD claims (please tick✓).					
	Not frequent 1	2	3	4	*Most frequent* 5
Contractual provisions not properly identified to support claim	❑	❑	❑	❑	❑
Conflicting interpretation of contractual provisions	❑	❑	❑	❑	❑
Failure to establish causal link	❑	❑	❑	❑	❑
Inadequate supporting documentation on quantum	❑	❑	❑	❑	❑
Insufficient breakdown of claim amount	❑	❑	❑	❑	❑
Inadequate effort at mitigation	❑	❑	❑	❑	❑
Lack of timely notice	❑	❑	❑	❑	❑
Inadequate/incorrect notice	❑	❑	❑	❑	❑
Others (please specify)	❑	❑	❑	❑	❑

Section B: Delay Analysis Methodologies and their Usage

8. Please indicate your level of awareness of each of the following methodologies for analysing delays (Indicate by ticking ✓ the appropriate box).					
	Virtually unaware 1	2	3	4	*Highly aware* 5
S-curve	❑	❑	❑	❑	❑
Global method	❑	❑	❑	❑	❑
Net impact	❑	❑	❑	❑	❑
As planned vrs. As built	❑	❑	❑	❑	❑
Impacted as-planned	❑	❑	❑	❑	❑
Collapsed as-built	❑	❑	❑	❑	❑
Window analysis	❑	❑	❑	❑	❑
Time impact analysis	❑	❑	❑	❑	❑
Other (please specify) ______________________	❑	❑	❑	❑	❑

9. Please indicate the extent to which you use each of the following methodologies for analysing delay claims (Indicate by ticking ✓ the appropriate box).					
	Very Low 1	2	3	4	*Very High* 5
S-curve	❑	❑	❑	❑	❑
Global method	❑	❑	❑	❑	❑
Net impact	❑	❑	❑	❑	❑
As planned vrs. As built	❑	❑	❑	❑	❑
Impacted as-planned	❑	❑	❑	❑	❑
Collapsed as-built	❑	❑	❑	❑	❑
Window analysis	❑	❑	❑	❑	❑
Time impact analysis	❑	❑	❑	❑	❑
Other (please specify) ______	❑	❑	❑	❑	❑

10. Please indicate the level of success with claims analysed by each of the following methodologies (Indicate by ticking ✓ the appropriate box).					
	Very Low 1	2	3	4	*Very High* 5
S-curve	❑	❑	❑	❑	❑
Global method	❑	❑	❑	❑	❑
Net impact	❑	❑	❑	❑	❑
As planned vrs. As built	❑	❑	❑	❑	❑
Impacted as-planned	❑	❑	❑	❑	❑
Collapsed as-built	❑	❑	❑	❑	❑
Window analysis	❑	❑	❑	❑	❑
Time impact analysis	❑	❑	❑	❑	❑
Other (please specify) ______	❑	❑	❑	❑	❑

11. Please indicate how frequently each of the following methodologies for analysing delays is challenged in practice (Indicate by ticking ✓ the appropriate box).					
	Never 1	2	3	4	*Always* 5
S-curve	❑	❑	❑	❑	❑
Global method	❑	❑	❑	❑	❑
Net impact	❑	❑	❑	❑	❑
As planned vrs. As built	❑	❑	❑	❑	❑
Impacted as-planned	❑	❑	❑	❑	❑
Collapsed as-built	❑	❑	❑	❑	❑
Window analysis	❑	❑	❑	❑	❑
Time impact analysis	❑	❑	❑	❑	❑
Other (please specify)	❑	❑	❑	❑	❑

12. The applicability of delay and disruption methodologies to any claim situation depends upon a number of factors. Please rank the following factors, including any additional factors, based on their degree of importance in choosing an appropriate methodology (please tick ✓).

	Least important 1	2	3	4	*Most important* 5
Availability of records	❑	❑	❑	❑	❑
Availability of baseline programme	❑	❑	❑	❑	❑
Nature of baseline programme	❑	❑	❑	❑	❑
Availability of updated programmes	❑	❑	❑	❑	❑
The stage of the project	❑	❑	❑	❑	❑
Reason for the delay analysis	❑	❑	❑	❑	❑
The other party to the claim	❑	❑	❑	❑	❑
Applicable legislation	❑	❑	❑	❑	❑
The type of contract	❑	❑	❑	❑	❑
The cost of using the technique	❑	❑	❑	❑	❑
The size of the project	❑	❑	❑	❑	❑
The duration of the project	❑	❑	❑	❑	❑
The complexity of the project	❑	❑	❑	❑	❑
The nature of the delaying events	❑	❑	❑	❑	❑
The skills of the analyst	❑	❑	❑	❑	❑
The amount in dispute	❑	❑	❑	❑	❑
Dispute resolution forum	❑	❑	❑	❑	❑
Number of delays requiring analysis	❑	❑	❑	❑	❑
Others (please specify) ______________	❑	❑	❑	❑	❑

13. Most practitioners/commentators have sought to explain the relatively low of the methodologies by pointing out perceived obstacles to their successful usage. Please indicate how frequently each of the following factors has been an obstacle to the use of the methodologies in practice (Please tick✓).

	Not frequent 1	2	3	4	*Most frequent* 5
Lack of familiarity with the technique	❑	❑	❑	❑	❑
High cost involved in its use	❑	❑	❑	❑	❑
Difficulty in using the technique	❑	❑	❑	❑	❑
High time consumption in using technique	❑	❑	❑	❑	❑
Baseline programme without CPM network	❑	❑	❑	❑	❑
Lack of skills in using technique	❑	❑	❑	❑	❑
Lack of suitable programming software	❑	❑	❑	❑	❑
Unrealistic baseline programme	❑	❑	❑	❑	❑
Poorly updated programmes	❑	❑	❑	❑	❑
Lack of adequate project information	❑	❑	❑	❑	❑
Others (please specify) ______________	❑	❑	❑	❑	❑
______________	❑	❑	❑	❑	❑

Section C: Disruption Analysis Methodologies and their Usage

14. Please indicate your level of awareness of each of the following methodologies for analysing disruption claims (Indicate by ticking ✓ the appropriate box).

	Virtually unaware 1	2	3	4	*Highly aware* 5
Measured Mile (or Productivity comparison)	❑	❑	❑	❑	❑
Industry standards and charts	❑	❑	❑	❑	❑
Global (total) method	❑	❑	❑	❑	❑
Modified global method	❑	❑	❑	❑	❑
System dynamics	❑	❑	❑	❑	❑
Earned value management	❑	❑	❑	❑	❑
Time and motion studies	❑	❑	❑	❑	❑
Other (please specify) ______________________	❑	❑	❑	❑	❑

15. Please indicate the extent to which you use each of the following methodologies for analysing disruption claims (Indicate by ticking ✓ the appropriate box).

	Very low 1	2	3	4	*Very high* 5
Measured Mile (or Productivity comparison)	❑	❑	❑	❑	❑
Industry standards and charts	❑	❑	❑	❑	❑
Global (total) method	❑	❑	❑	❑	❑
Modified global method	❑	❑	❑	❑	❑
System dynamics	❑	❑	❑	❑	❑
Earned value management	❑	❑	❑	❑	❑
Time and motion studies	❑	❑	❑	❑	❑
Other (please specify) ______________________	❑	❑	❑	❑	❑

16. Please indicate the level of success with disruption claims analysed by each of the following methodologies (Indicate by ticking ✓ the appropriate box).

	Very low 1	2	3	4	*Very high* 5
Measured Mile (or Productivity comparison)	❑	❑	❑	❑	❑
Industry standards and charts	❑	❑	❑	❑	❑
Global (total) method	❑	❑	❑	❑	❑
Modified global method	❑	❑	❑	❑	❑
System dynamics	❑	❑	❑	❑	❑
Earned value management	❑	❑	❑	❑	❑
Time and motion studies	❑	❑	❑	❑	❑
Other (please specify) ______________________	❑	❑	❑	❑	❑

17. Please indicate how frequently each of the following methodologies for establishing disruption is challenged in practice (Indicate by ticking ✓ the appropriate box).

	Never 1	2	3	4	*Always* 5
Measured Mile (or Productivity comparison)	❑	❑	❑	❑	❑
Industry standards and charts	❑	❑	❑	❑	❑
Global (total) method	❑	❑	❑	❑	❑
Modified global method	❑	❑	❑	❑	❑
Jury verdict	❑	❑	❑	❑	❑
System dynamics	❑	❑	❑	❑	❑
Earned value management	❑	❑	❑	❑	❑
Time and motion studies	❑	❑	❑	❑	❑
Other (please specify) ______________	❑	❑	❑	❑	❑

18. Please provide comments on what you think generally are the main problems affecting the analysis and resolution of DD claims. (You may attach additional sheet for continuation).

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19. Would you be prepared to grant us an interview to further solicit your opinions on the planning and programme issues raised by the DD analysis practice?		
	YES ❑	NO ❑
20. For purposes of the above, follow-up and relaying the research findings to interested participants, could you please provide us with the following information (this is however, optional).		

Name of Respondent: ______________________________

Position within organisation:______________________________

Name of organisation:______________________________

Address: ______________________________

Telephone: ________________ Fax:________________

E-mail: ____________________

Thank you very much for your time

NB: *Confidentiality and anonymity are guaranteed. All information collected will conform to the University's Human Research Ethical procedures.*

Appendix B: Correlation matrix of DAM selection factors

Correlation Matrix[a]

	Recordav	Basepro	Natbas	Updtpg	Tmdly	Reasdly	Othpty	Apllgis	Typecnt	Costec	Sizeprj	Duraprj	Cmplxpjt	Natdly	Sklanly	Amtdsp	Dsptrs	Nmbdly
Recordav	1.000																	
Basepro	0.236	1.000																
Natbas	0.180	0.495*	1.000															
Updtpg	0.066	0.133	0.163	1.000														
Tmdly	0.019	0.351	0.201	0.260	1.000													
Reasdly	0.025	-0.065	-0.341	0.160	0.637**	1.000												
Othpty	-0.030	0.286	-0.019	0.048	-0.077	0.314	1.000											
Apllgis	-0.143	0.105	-0.184	0.398	0.133	0.334	0.367	1.000										
Typecnt	0.019	0.152	-0.090	0.456*	0.253	0.312	0.268	0.407*	1.000									
Costec	0.084	-0.196	-0.078	-0.029	-0.216	0.115	0.027	-0.092	0.075	1.000								
Sizeprj	-0.102	0.132	-0.023	0.304	0.067	0.207	0.382	0.302	0.271	0.275	1.000							
Duraprj	-0.155	0.151	0.057	0.393	0.198	0.166	0.329	0.296	0.340	0.102	0.803*	1.000						
Cmplxpjt	0.042	0.156	0.045	0.029	-0.012	0.232	0.360	0.121	0.144	0.027	0.428*	0.471*	1.000					
Natdly	0.063	0.277	0.108	0.300	0.316	0.209	0.275	0.220	0.319	-0.248	0.432*	0.440*	0.343	1.000				
Sklanly	-0.046	0.084	-0.077	0.481*	0.157	0.176	0.328	0.157	0.189	0.532**	0.548*	0.479*	0.164	0.288	1.000			
Amtdsp	0.149	0.085	0.054	0.217	0.081	0.163	0.415*	0.093	0.162	0.173	0.444*	0.439*	0.432*	0.472*	0.322	1.000		
Dsptrs	0.069	0.177	0.135	0.368	0.067	0.205	0.252	0.396	0.440**	0.279	0.415*	0.401*	0.208	0.172	0.451*	0.301	1.000	
Nmbdly	0.078	-0.088	-0.056	0.280	0.249	0.103	-0.066	-0.082	0.124	0.092	0.226	0.493*	0.218	0.331	0.296	0.340	0.267	1.000

a Determinant = 8.603E-04; *Correlation is significant at the 0.01 level ; ** Correlation is significant at the 0.05 level

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy	0.718
Bartlett's Test of Sphericity	Approx. Chi-Square = 834.05
	df = 153; Sig. p =0.0000

APPENDIX C: Interview questionnaire for Investigating Programming Issues affecting DDA

Section A General Information (Optional)

Name of Respondent:..

Position within organisation:..

Name of organisation: ....

Years of Experience in planning and programming:................................

Address:...

....

Telephone:....................................... Fax:...

E-mail:..

Section B Preconstruction stage Programming

1. What programming format do you often use in preparing baseline programmes?

    ____

2. Is this format usually adopted in compliance with programming specifications of the contract? Yes/No

    ____

3. If **No** to Q2, what are the reasons for adopting this format?

    ____

    ____

    ____

    ____

4. What programming software is usually used in preparing baseline programmes?

    ____

5. Who are those (type of staff) often involved in the preparation of baseline programmes? Please rank their level of involvement on a scale of 1-5 (1= lowest involvement and 5= highest involvement).

____

____

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6. Do you often carry out resource loading as part of the baseline programme development? Yes/No

____

7. If **No** to Q6, Please provide reasons why this is not so.

____

____

____

8. Do you often carry out resource levelling as part of the baseline programme development? Yes/No

____

9. If **No** to Q8, Please provide reasons why this is not so.

____

____

____

____

10. Which other time and cost management tools are usually developed during preconstruction stage programming?

Tools	**Developed?**
Manpower loading graph	
Earned value management	
Method statement	
Others: Please specify	

11. What are the main uses of baseline programmes?

____

____

____

Section B Construction Stage Programming

12. Is the baseline programme updated periodically during the course of a project? Yes/No.

____

13. If **Yes** to Q12, what updating frequency is often adopted?

____

14. Who are those (type of staff) often involved in updating the programme? Please rank their level of involvement on a scale of 1-5 (1= lowest involvement and 5= highest involvement).

____

15. Do you always produce progress report for an employer? Yes/No

16. If **Yes** to Q15, how frequently do you produce this? (Rate this frequency on a scale of 1-5; 1=never and 5 for always).

17. If **Yes** to Q15, please state the information items that are usually reported on.

18. How frequently do you track or keep records of crew productivity (manhours/units installed) for various major project activities?

    Rank on a scale of 1-5: 1=never and 5=always

19. Please comment on what you think generally are the main problems affecting proper programming practice

Thank you very much for your time

APPENDIX D: SPEARMAN RANK ORDER CORRELATIONS

(i) Correlations between awareness and use of DAMs - Construction Organisation

(ii) Correlations between awareness and use of DAMs – Consulting Organisation

(iii) Correlations between success and challenge of DAMs - Construction Organisation

(iv) Correlations between success and challenge of DAMs – Consulting Organisation

(v) Correlations between awareness and use of DSAMs - Construction Organisation

(vi) Correlations between awareness and use of DSAMs – Consulting Organisation

(vii) Correlations between success and challenge of DSAMs - Construction Organisation

(viii) Correlations between success and challenge of DSAMs – Consulting Organisation

(i) Correlations between Awareness and use of DAMs - Construction Organisation

		S-Curve	Global method	Net impact	As planned vrs. as Built	Impacted as-planned	Collapsed as-built method	Window analysis	Time impact
S-Curve	Corre.Coeff.	0.616	0.449	0.149	-0.109	0.073	0.149	0.637	0.594
	Sig. (2-tailed)	0.000	0.000	0.245	0.396	0.570	0.246	0.000	0.000
	N	61	63	63	63	63	62	63	62
Global method	Corre.Coeff.	0.182	0.441	0.407	0.237	0.269	0.309	0.232	0.310
	Sig. (2-tailed)	0.160	0.000	0.001	0.061	0.033	0.015	0.067	0.014
	N	61	63	63	63	63	62	63	62
Net impact	Corre.Coeff.	0.073	-0.011	0.518	0.396	0.384	0.332	0.025	0.087
	Sig. (2-tailed)	0.574	0.930	0.000	0.001	0.002	0.008	0.849	0.502
	N	61	63	63	63	63	62	63	62
As planned vrs. as Built	Corre.Coeff.	0.078	0.268	0.391	0.381	0.241	0.312	0.133	0.233
	Sig. (2-tailed)	0.552	0.034	0.002	0.002	0.057	0.013	0.299	0.069
	N	61	63	63	63	63	62	63	62
Impacted as-planned	Corre.Coeff.	0.079	0.173	0.459	0.500	0.454	0.391	0.069	0.099
	Sig. (2-tailed)	0.544	0.174	0.000	0.000	0.000	0.002	0.593	0.442
	N	61	63	63	63	63	62	63	62
Collapsed as-built	Corre.Coeff.	0.083	0.142	0.184	0.239	0.321	0.665	0.241	0.405
	Sig. (2-tailed)	0.525	0.268	0.149	0.060	0.010	0.000	0.057	0.001
	N	61	63	63	63	63	62	63	62
Window analysis	Corre.Coeff.	0.379	0.233	-0.012	-0.139	-0.104	0.198	0.710	0.655
	Sig. (2-tailed)	0.003	0.066	0.925	0.276	0.419	0.123	0.000	0.000
	N	61	63	63	63	63	63	63	62
Time impact	Corre.Coeff.	0.577	0.444	0.191	-0.204	-0.078	0.167	0.688	0.806
	Sig. (2-tailed)	0.000	0.000	0.136	0.112	0.548	0.194	0.000	0.000
	N	63	63	62	62	63	62	62	62

(ii) Correlations between Awareness and use of DAMs - Consulting Organisation

		S-Curve	Global method	Net impact	As planned vrs. as Built	Impacted as-planned	Collapsed as-built method	Window analysis	Time impact
S-Curve	Corre.Coeff.	0.468	0.018	0.136	-0.205	0.024	0.244	0.290	0.031
	Sig. (2-tailed)	0.008	0.889	0.286	0.105	0.853	0.052	0.019	0.809
	N	65	67	67	67	64	66	65	65
Global method	Corre.Coeff.	0.134	0.375	0.151	-0.162	-0.026	0.160	0.306	0.193
	Sig. (2-tailed)	0.293	0.077	0.234	0.196	0.841	0.206	0.013	0.120
	N	67	65	67	66	64	67	64	63
Net impact	Corre.Coeff.	0.054	-0.048	0.228	0.153	-0.068	0.002	0.259	0.194
	Sig. (2-tailed)	0.674	0.705	0.035	0.228	0.595	0.990	0.037	0.121
	N	66	66	65	64	64	67	65	63
As planned vrs. as Built	Corre.Coeff.	0.110	0.033	0.161	0.198	0.125	0.190	0.274	0.130
	Sig. (2-tailed)	0.388	0.797	0.205	0.029	0.325	0.133	0.027	0.298
	N	66	65	64	67	67	64	65	66
Impacted as-planned	Corre.Coeff.	0.160	-0.026	0.165	-0.121	0.410	0.192	0.520	0.284
	Sig. (2-tailed)	0.206	0.838	0.193	0.343	0.018	0.129	0.000	0.022
	N	64	67	67	64	64	64	65	65
Collapsed as-built	Corre.Coeff.	-0.237	-0.370	-0.196	-0.260	-0.201	0.277	0.531	-0.018
	Sig. (2-tailed)	0.060	0.003	0.120	0.038	0.111	0.003	0.000	0.888
	N	67	64	67	66	67	66	67	67
Window analysis	Corre.Coeff.	-0.086	-0.295	-0.090	-0.215	-0.219	0.046	0.431	0.183
	Sig. (2-tailed)	0.499	0.018	0.479	0.089	0.083	0.716	0.000	0.145
	N	65	64	64	67	67	64	65	65
Time impact	Corre.Coeff.	-0.129	-0.004	0.020	-0.124	-0.031	-0.194	0.293	0.289
	Sig. (2-tailed)	0.308	0.972	0.873	0.326	0.809	0.125	0.018	0.019
	N	63	65	66	65	66	66	65	67

(iii) Correlations between success and challenge of DAMs - Construction Organisation

		S-Curve	Global method	Net impact	As planned vrs. as Built	Impacted as-planned	Collapsed as-built method	Window analysis	Time impact
S-Curve	Corre.Coeff.	0.274	-0.197	-0.122	0.118	0.190	0.368	0.414	0.377
	Sig. (2-tailed)	0.045	0.150	0.378	0.393	0.173	0.007	0.003	0.006
	N	60	61	61	63	63	62	62	62
Global method	Corre.Coeff.	0.172	-0.174	-0.174	0.095	0.033	-0.003	0.186	0.171
	Sig. (2-tailed)	0.210	0.003	0.205	0.482	0.812	0.985	0.186	0.226
	N	63	60	61	61	62	62	59	62
Net impact	Corre.Coeff.	0.148	0.147	0.191	0.071	0.116	0.057	0.167	0.100
	Sig. (2-tailed)	0.285	0.286	0.038	0.604	0.404	0.687	0.237	0.482
	N	61	63	63	63	63	62	63	62
As planned vrs. as Built	Corre.Coeff.	-0.534	0.365	0.197	-0.203	-0.011	-0.191	-0.418	-0.399
	Sig. (2-tailed)	0.000	0.006	0.154	0.016	0.937	0.171	0.002	0.004
	N	61	61	63	63	62	62	63	63
Impacted as-planned	Corre.Coeff.	-0.346	0.421	0.229	-0.027	-0.056	-0.123	-0.406	-0.298
	Sig. (2-tailed)	0.011	0.001	0.095	0.843	0.009	0.381	0.003	0.034
	N	60	63	61	63	63	62	63	62
Collapsed as-built	Corre.Coeff.	0.127	0.353	0.266	-0.010	0.199	-0.150	0.090	0.058
	Sig. (2-tailed)	0.364	0.008	0.052	0.944	0.149	0.030	0.530	0.681
	N	62	62	62	62	63	61	63	63
Window analysis	Corre.Coeff.	0.588	-0.208	-0.075	0.225	0.136	0.451	-0.442	0.533
	Sig. (2-tailed)	0.000	0.131	0.592	0.098	0.332	0.001	0.000	0.000
	N	59	59	62	62	61	60	60	61
Time impact	Corre.Coeff.	0.636	-0.284	-0.137	0.256	0.285	0.491	0.681	-0.505
	Sig. (2-tailed)	0.000	0.035	0.325	0.056	0.037	0.000	0.000	0.000
	N	62	62	63	63	61	62	63	63

(iv) Correlations between Success and Challenge of DAMs – Consulting Organisation

		S-Curve	Global method	Net impact	As planned vrs. as Built	Impacted as-planned	Collapsed as-built method	Window analysis	Time impact
S-Curve	Corre.Coeff.	-0.352	-0.525	-0.581	-0.516	-0.422	-0.573	-0.554	-0.399
	Sig. (2-tailed)	0.007	0.000	0.000	0.000	0.001	0.000	0.000	0.002
	N	66	67	65	65	67	66	64	63
Global method	Corre.Coeff.	-0.333	-0.298	-0.518	-0.330	-0.389	-0.546	-0.511	-0.311
	Sig. (2-tailed)	0.011	0.021	0.000	0.011	0.003	0.000	0.000	0.015
	N	66	65	64	66	64	67	64	65
Net impact	Corre.Coeff.	-0.408	-0.487	0.443	-0.338	-0.376	-0.539	-0.464	-0.272
	Sig. (2-tailed)	0.001	0.000	0.000	0.009	0.004	0.000	0.000	0.037
	N	66	65	67	66	64	65	66	66
As planned vrs. as Built	Corre.Coeff.	-0.327	-0.300	-0.303	-0.365	-0.192	-0.319	-0.472	-0.309
	Sig. (2-tailed)	0.012	0.019	0.018	0.004	0.149	0.013	0.000	0.014
	N	65	65	63	67	66	66	65	65
Impacted as-planned	Corre.Coeff.	-0.203	-0.084	0.020	0.004	-0.256	-0.049	-0.071	-0.133
	Sig. (2-tailed)	0.127	0.527	0.879	0.976	0.989	0.711	0.594	0.315
	N	67	67	67	67	65	66	66	66
Collapsed as-built	Corre.Coeff.	0.170	0.337	0.522	0.481	0.138	-0.281	0.323	0.166
	Sig. (2-tailed)	0.201	0.009	0.000	0.000	0.307	0.031	0.013	0.209
	N	63	63	64	67	67	67	64	65
Window analysis	Corre.Coeff.	0.248	0.443	0.556	0.523	0.225	0.516	-0.488	0.305
	Sig. (2-tailed)	0.060	0.000	0.000	0.000	0.093	0.000	0.000	0.018
	N	66	66	65	65	65	66	66	66
Time impact	Corre.Coeff.	-0.046	0.274	0.392	0.336	0.118	0.114	0.024	-0.321
	Sig. (2-tailed)	0.730	0.032	0.002	0.008	0.382	0.388	0.856	0.032
	N	65	67	65	66	67	66	64	63

(v) Correlations between Awareness and use of DSAMs - Construction Organisation

		Measured mile	Industry studies/charts	Global method	Modifield global	System dynamics	Earned Value Mangt	Time & motion studies
Measured mile	Corre.Coeff.	0.419	0.229	0.131	0.138	0.177	0.315	-0.123
	Sig. (2-tailed)	0.001	0.073	0.315	0.289	0.172	0.013	0.339
	N	62	62	63	61	61	62	62
Industry studies/charts	Corre.Coeff.	0.324	0.584	0.252	0.265	0.200	0.261	0.171
	Sig. (2-tailed)	0.010	0.000	0.050	0.039	0.123	0.040	0.184
	N	62	63	61	63	61	63	62
Global method	Corre.Coeff.	-0.179	0.203	0.737	0.609	-0.231	0.036	-0.145
	Sig. (2-tailed)	0.163	0.113	0.000	0.000	0.073	0.783	0.261
	N	62	62	63	61	61	62	63
Modifield global	Corre.Coeff.	-0.065	0.117	0.382	0.641	-0.055	0.053	0.018
	Sig. (2-tailed)	0.618	0.363	0.002	0.000	0.675	0.680	0.892
	N	62	62	61	61	61	62	62
System dynamics	Corre.Coeff.	0.467	0.468	-0.295	-0.047	0.679	0.292	0.538
	Sig. (2-tailed)	0.000	0.000	0.021	0.719	0.000	0.021	0.000
	N	62	62	63	61	61	62	62
Earned Value Mangt	Corre.Coeff.	0.023	0.305	0.313	0.398	0.227	0.840	-0.041
	Sig. (2-tailed)	0.859	0.016	0.014	0.002	0.079	0.000	0.751
	N	62	62	61	61	63	62	62
Time & motion studies	Corre.Coeff.	0.618	0.439	-0.313	-0.231	0.280	-0.044	0.701
	Sig. (2-tailed)	0.000	0.000	0.014	0.073	0.029	0.731	0.000
	N	62	62	63	61	63	62	63

(vi) Correlations between Awareness and use of DSAMs – Consulting Organisation

		Measured mile	Industry studies/charts	Global method	Modifield global	System dynamics	Earned Value Mangt	Time & motion studies
Measured mile	Corre.Coeff.	0.341	0.374	-0.113	0.156	0.174	0.220	-0.009
	Sig. (2-tailed)	0.007	0.003	0.380	0.227	0.183	0.089	0.943
	N	67	66	64	62	60	61	62
Industry studies/charts	Corre.Coeff.	0.132	0.768	-0.229	-0.205	0.108	0.175	-0.051
	Sig. (2-tailed)	0.307	0.000	0.073	0.109	0.413	0.178	0.693
	N	63	65	66	65	66	65	67
Global method	Corre.Coeff.	0.197	0.305	0.256	0.172	0.061	0.163	-0.215
	Sig. (2-tailed)	0.125	0.016	0.038	0.181	0.645	0.208	0.094
	N	65	67	67	67	66	65	65
Modifield global	Corre.Coeff.	0.230	0.209	-0.086	0.430	0.094	0.180	-0.018
	Sig. (2-tailed)	0.072	0.104	0.506	0.002	0.475	0.165	0.892
	N	65	64	64	67	64	65	65
System dynamics	Corre.Coeff.	0.095	0.317	-0.451	-0.251	0.656	0.510	0.201
	Sig. (2-tailed)	0.466	0.013	0.000	0.051	0.000	0.000	0.121
	N	67	64	67	66	66	67	67
Earned Value Mangt	Corre.Coeff.	0.249	0.130	-0.169	0.086	0.386	0.547	0.030
	Sig. (2-tailed)	0.053	0.318	0.193	0.512	0.002	0.000	0.819
	N	66	66	65	64	67	65	63
Time & motion studies	Corre.Coeff.	0.161	0.309	-0.215	0.013	0.338	0.311	0.201
	Sig. (2-tailed)	0.216	0.015	0.096	0.921	0.009	0.015	0.028
	N	66	65	64	67	64	65	66

(vii) Correlations between success and challenge of DSAMs - Construction Organisation

		Measured mile	Industry studies/charts	Global method	Modifield global	System dynamics	Earned Value Mangt	Time & motion studies
Measured mile	Corre.Coeff.	-0.182	-0.258	0.089	0.044	-0.169	0.091	-0.160
	Sig. (2-tailed)	0.004	0.055	0.520	0.757	0.245	0.529	0.257
	N	61	61	60	60	63	63	62
Industry studies/charts	Corre.Coeff.	0.053	-0.231	0.025	0.066	0.197	0.238	0.317
	Sig. (2-tailed)	0.698	0.009	0.853	0.640	0.174	0.096	0.021
	N	63	62	63	61	61	63	61
Global method	Corre.Coeff.	-0.028	0.235	-0.156	-0.130	0.490	0.131	0.257
	Sig. (2-tailed)	0.836	0.082	0.000	0.353	0.000	0.370	0.066
	N	60	63	62	61	63	62	63
Modifield global	Corre.Coeff.	-0.118	0.089	-0.120	0.205	0.180	-0.120	-0.045
	Sig. (2-tailed)	0.397	0.519	0.382	0.036	0.215	0.413	0.753
	N	63	62	62	63	61	62	63
System dynamics	Corre.Coeff.	0.177	-0.035	-0.238	-0.235	-0.303	0.036	0.166
	Sig. (2-tailed)	0.204	0.805	0.086	0.098	0.002	0.810	0.249
	N	62	62	61	59	63	61	60
Earned Value Mangt	Corre.Coeff.	0.072	0.014	0.115	-0.110	-0.007	-0.521	0.160
	Sig. (2-tailed)	0.604	0.919	0.414	0.443	0.962	0.009	0.263
	N	63	62	63	63	62	63	61
Time & motion studies	Corre.Coeff.	0.084	0.146	-0.415	-0.131	0.429	0.178	0.295
	Sig. (2-tailed)	0.541	0.282	0.002	0.348	0.002	0.216	0.001
	N	63	62	63	63	63	63	61

(viii) Correlations between success and challenge of DSAMs - Consulting Organisation

		Measured mile	Industry studies/charts	Global method	Modifield global	System dynamics	Earned Value Mangt	Time & motion studies
Measured mile	Corre.Coeff.	-0.303	0.141	0.657	0.442	0.328	0.321	0.272
	Sig. (2-tailed)	0.019	0.280	0.000	0.000	0.020	0.015	0.041
	N	66	65	67	65	64	65	66
Industry studies/charts	Corre.Coeff.	0.250	0.227	0.501	0.224	0.243	0.079	0.152
	Sig. (2-tailed)	0.054	0.032	0.000	0.088	0.089	0.560	0.257
	N	65	66	65	64	67	65	63
Global method	Corre.Coeff.	0.124	0.326	-0.133	-0.079	0.116	0.169	0.161
	Sig. (2-tailed)	0.344	0.010	0.008	0.554	0.420	0.210	0.231
	N	63	64	61	59	50	57	57
Modifield global	Corre.Coeff.	0.082	0.189	0.094	0.212	0.088	0.162	0.145
	Sig. (2-tailed)	0.532	0.145	0.471	0.005	0.543	0.228	0.281
	N	63	64	63	65	66	67	67
System dynamics	Corre.Coeff.	0.008	-0.162	-0.316	-0.207	-0.042	0.058	0.071
	Sig. (2-tailed)	0.955	0.230	0.017	0.125	0.008	0.682	0.613
	N	66	67	66	65	65	63	64
Earned Value Mangt	Corre.Coeff.	0.115	0.034	0.162	0.113	0.122	-0.459	0.129
	Sig. (2-tailed)	0.385	0.794	0.215	0.394	0.397	0.022	0.345
	N	64	66	65	66	66	67	67
Time & motion studies	Corre.Coeff.	0.172	0.206	-0.116	0.035	0.406	0.434	0.419
	Sig. (2-tailed)	0.190	0.112	0.374	0.792	0.003	0.001	0.002
	N	67	64	65	64	66	63	64

Appendix E

- **Cover letter for validation questionnaire survey**
- **Copy of validation questionnaire**

Cover letter for validation questionnaire survey

Author's Address

Name
Company
Address

3rd March 2008

Dear…….

ASSISTANCE FOR EXPERT VALIDATION OF A MODEL FOR SELECTING APPROPRIATE DELAY ANALYSIS METHODOLOGY

You may recall the questionnaire survey on the use of delay analysis methodologies (DAM) in the UK that was sent to you for feedback some 16 months ago. Under the sponsorship of University of Wolverhampton, this survey was carried out as part of a wider research work aimed at identifying current problems with delay and disruption analysis towards the development of an appropriate framework for improvement.

Information gathered from literature review, the survey and subsequent interviews was used to draw deductions and conclusions in respect of the research objectives. On the basis of the findings, a particular problem area was isolated for further consideration, namely: *The decision to select any of the myriad methodologies available for analysing delays in any claims situation requires careful consideration of a number of criteria but there is no decision aids available for analysts to rely on to ensure a more objective selection process.* In an attempt to redress this, a DAM selection decision model is proposed. The model is mainly based on scoring competing DAMs on 18 selection criteria identified as relevant from a thorough review on the body of literature on delay analysis and the questionnaire survey.

It is thought that this model will be a very useful resource to practitioners, particularly for analysts faced with the need to justify a chosen methodology to their clients or triers-of-fact. However, to ensure that the model is valid for use in practice, there is the need for experts' validation. The purpose of this letter is therefore to seek your assistance on this task of expert evaluation. In this respect, I have enclosed a copy of the model together with a worked example to clarify its application. Also enclosed is a questionnaire indicating areas where your comments are sought.

The research is in its conclusion stage, so it would be of a great help to me if the completed questionnaire is returned using the enclosed stamped addressed envelope by 24th March 2008. If you are unable to complete the questionnaire, any general comment you are able to offer would be much appreciated. All information received will be treated as strictly confidential.

Please do not hesitate to contact me for further details or clarifications if there are any particular points on the model that are unclear. I would be happy to discuss any queries by telephone, e-mail or via a meeting with you, whichever is preferable.

We do appreciate that this validation will take some of your valuable time but without the kind contribution of experts like yourself, the continuing search for solutions to problems of delay analysis would not be successful.

Please return the completed questionnaire in the self-addressed stamped envelope provided to the address below or return it by fax.

Many thanks and look forward to hearing from you soon.

Yours sincerely

Nuhu Braimah
(PhD Research Student)

School of Engineering and the
Built Environment (SEBE)
University of Wolverhampton

A QUESTIONAIRE FOR VALIDATING A MODEL FOR THE SELECTION OF DELAY ANALYSIS METHODOLOGY

The aim of this questionnaire is to gather and assess experts' opinions on the attached model, which is intended for assisting analysts in the selection of appropriate delay analysis methodology. This is meant for validating the proposed model as to its significance to the industry, workability in practice and adequacy in addressing the decision problem confronting analysts on DAM selection.

The questionnaire is in three (3) parts. **Section A** seeks to collect information on your background; **Sections B and C** ask for your opinions or comments on general and specific aspects of the model, respectively. There are no correct or incorrect responses, only your much-needed opinion.

Please return the completed questionnaire in the self-addressed stamped envelope provided to the address below or return it by fax.

We would like to thank you in advance for your valued and kind consideration.

If you would like any further information about the research, please let me know.

Nuhu Braimah
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Section A: Background of Respondent

Name of Respondents (optional):……………………………………………………………
Profession: ………………………………………………………………………………..
Qualification:………………………………………………………………………………
Work your organisation is involved in:…………………………………………………………   …………………………………………………………
Current job designation:………………………………………………………………………..
Years of experience in delay and disruption claims resolutions: …………………………...

Section B: General Impression on the model

1. Does the model address an important problem in the field of delay and disruption analysis?
yes, quite significant ❑   yes, but not significant ❑   no, would make no difference ❑   not sure of its significance ❑   Comments (if any)……………………………………………………………………………..   ………………………………………………………………………………………………   ………………………………………………………………………………………………
2. Would you say the model is capable of assisting analysts in the selection of appropriate delay analysis methodology?
yes, highly capable ❑   yes, capable ❑   no, not capable ❑   not sure of its capability ❑   Comments (if any)……………………………………………………………………………..   ………………………………………………………………………………………………   ……………………………………………………………………………………………..
3. Would you say the model is simple, clear and easy to understand and use with little or no practical difficulties?
Yes ❑   No ❑
4. If **No** to **Q3**, please comment on the specific aspects of the model that, in your view, are likely to cause major difficulties to its use.   ………………………………………………………………………………………………   ……………………………………………………………………………………………….   ……………………………………………………………………………………………….   ………………………………………………………………………………………………   ………………………………………………………………………………………………
5. What is your opinion on the resources needed to apply the model in real life selection exercise?
would be too costly to operate at current resource levels ❑   would not be too costly to operate at current resource levels ❑   the benefits of using the model justifies any resource requirements ❑   Comment (if any)……………………………………………………………………………..   ………………………………………………………………………………………………

6. What is your opinion on the description of the model and its lay out?
comprehensive ❑ adequate ❑ poor ❑ Comment (if any)…………………………………………………………………………………… ……………………………………………………………………………………………………… ………………………………………………………………………………………………………
7. In your opinion, are there any further matters of importance which ought to be included in the model or considered?
Yes ❑ No ❑
8. If **Yes** to **Q7**, please specify: ……………………………………………………………………………………………………. …………………………………………………………………………………………………… ……………………………………………………………………………………………………. …………………………………………………………………………………………………….. ……………………………………………………………………………………………………..

Section C: Impression on the model's techniques

9. What is your opinion on the scale of "0-1" adopted for rating the methodologies against the selection criteria?
very suitable ❑ suitable ❑ not suitable ❑ not sure of its suitability ❑ Comments (if any)…………………………………………………………………………………… ……………………………………………………………………………………………………… ………………………………………………………………………………………………………
10. What is your opinion on the approaches/methods proposed for evaluating the selection criteria in rating the methodologies?
very suitable ❑ suitable ❑ not suitable ❑ not sure of its suitability ❑ Comments (if any)…………………………………………………………………………………… ……………………………………………………………………………………………………… ……………………………………………………………………………………………………..
11. Are there any further approaches/methods, which in your opinion are important to consider in rating the methodologies against the criteria?
Yes ❑ No ❑
12. If **Yes** to **Q11**, please specify: ……………………………………………………………………………………………… ……………………………………………………………………………………………… ……………………………………………………………………………………………… ………………………………………………………………………………………………
13. What is your opinion on the attributes of the delay analysis methodologies defined in Tables 2 to 6 and figure 1, in respect of the various selection criteria?
very suitable ❑ suitable ❑ not suitable ❑ not sure of its suitability ❑ Comments (if any)……………………………………………………………………………………

14. In your opinion, are there any other important attributes or characteristics that describe these methodologies but were not considered? Yes ❑ No ❑
15. If you have answered **Yes** to **Q14**, please list these attributes or characteristics of the methods that ought to have been considered. ……………………………………………………………………………………………… ……………………………………………………………………………………………… ……………………………………………………………………………………………… ……………………………………………………………………………………………… ……………………………………………………………………………………………… ………………………………………………………………………………………………. ………………………………………………………………………………………………… ………………………………………………………………………………………………..
16. Please provide any other general comments that you have on the model or suggestions for improvement (continue on a separate sheet if necessary) ………………………………………………………………………………………………................ ……………………………………………………………………………………………………… ……………………………………………………………………………………………………… ………………………………………………………………………………………………................ …………………………………………………………………………………………………….. …… ………………………………………………………………………………………………………. ………………………………………………………………………………………………………. ……………………………………………………………………………………………………….. ………………………………………………………………………………………………….. …………………………………………………………………………………………………… ………………………………………………………………………………………………….. ………………………………………………………………………………………………………

Thank you very much for your time

NB: *Confidentiality and anonymity are guaranteed. All information collected will conform to the University's Human Research Ethical procedures*